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Report on the:

Structural Evaluation

At the:

Milford, MA Live Fire Training Structure ("Burn Building")

EL&M No.: 22049

Prepared for:

Milford Fire Department

Prepared by:

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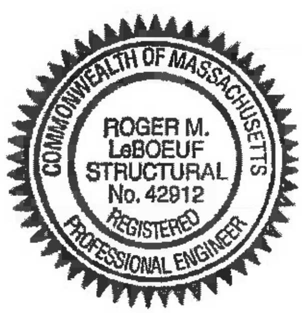
Training Center Designer

Roger M. LeBoeuf, S.E.
President

Date:

November 30, 2022



This report has been electronically signed and sealed by Roger M. LeBoeuf, S.E. on November 30, 2022 using a Digital Signature.

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Roger M. LeBoeuf
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1. Introduction

1.1 Purpose of Survey

The "burn building" at the Milford Fire Department Headquarters is a live fire training structure located at 21 Birch Street, Milford, MA, 01786. It is used for training firefighters in live fire training evolutions.

During conversations before the survey, the Client's representatives stated that there is evidence of structural damage due to repetitive fire exposure during training evolutions. The purpose of this survey is to determine the extent of any structural damage and make recommendations. Accomplishing this purpose will keep the Owner in conformance with NFPA's requirements for structural evaluations of the burn building for a maximum of 5 years, depending on the additional requirements of the Authority Having Jurisdiction, though EL&M recommends evaluating the structure at least every other year. This structural evaluation and report fulfill the requirements of NFPA 1402 for periodic structural evaluations of live fire training structures.

1.2 Description of Survey at this Burn Building

To accomplish the purpose, Mrs. Rebecca Hallinan, of Elliott, LeBoeuf & McElwain (EL&M), traveled to the site on November 3, 2022 to conduct a visual structural survey. Upon arriving at the burn building for the field survey, Mrs. Hallinan interviewed Chief Mark Nelson and Deputy Chief Michael DeTore of the Milford Fire Department. The interview included a walk-through of the burn building. During this interview, Mrs. Hallinan obtained information about the burn building history, condition, and use. Chief Nelson pointed out damage and enumerated specific concerns about the burn building.

After the interview and walk-through, Mrs. Hallinan conducted a non-destructive, visual structural survey of the burn building. Visual observations were made of exposed surfaces in every accessible room for the purpose of evaluating the general condition of the existing structural systems. Furthermore, exposed top and bottom surfaces (where accessible) of the concrete roof and elevated floor slabs were sounded in an attempt to locate delaminations. The exterior was observed from the ground and accessible roof locations. Although the burn building was generally clean during the survey, soot and other debris existed on many surfaces which impaired the ability to observe every surface clearly.

The survey did not include soils testing, materials testing, evaluation of structural load capacity, or evaluation of non-structural items, such as sprinkler pipes, or any items beyond the exterior walls of the burn building. The only non-structural items included in the survey were doors, window shutters, guardrails, and any other items indicated in the report. The assessment of non-structural items was limited to a visual assessment of their general condition. Testing and inspections were not performed on the non-structural items. For example, door and shutter hinges were not inspected or tested for wear or risk of failure, but visible corrosion and warping on doors would have been noted.

Evaluations of code compliance and other safety issues, such as door and window dimensions, egress requirements, and guardrail heights, were not included in the scope of work. The scope of the evaluation was limited to an evaluation of the visible condition of structural elements. Therefore, evaluations of fuel loads, training temperatures, training procedures, and other operational items were not performed. Only rooms with two doors or one door plus one window to a tenable location should be used as burn rooms, as required by NFPA 1402.

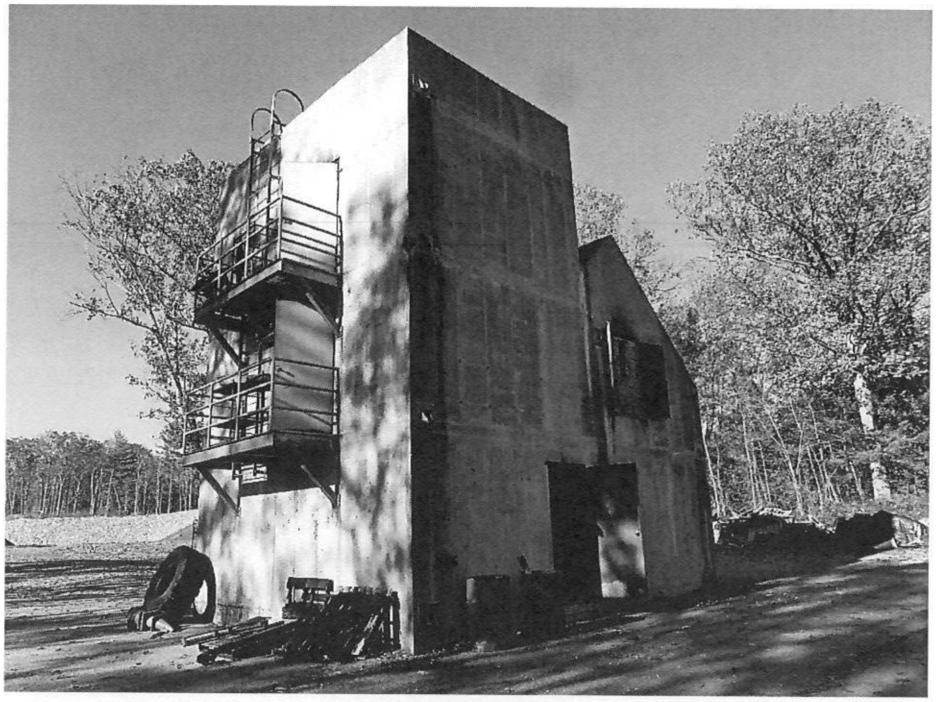
The original structural drawings were partially available for review during the survey. These drawings were prepared by Tsiang Engineering Inc. of West Newton, MA and dated June 7, 1989. The drawings were spot-checked in the field and were found to be a generally accurate representation of the exposed conditions. We have assumed that the drawings accurately reflect the as-built conditions of the existing structure, including the hidden conditions such as slab reinforcing.

The visual survey is a useful method for determining the general structural condition of the burn building. However, without exposing every hidden condition and without testing any of the structural materials for deterioration, the survey is not exhaustive. It is possible for damaged structural elements to appear undamaged at the exposed surface. There may be damage that was not detected during this survey and future damage can occur due to continued live fire training evolutions. Therefore, while it is believed that the survey provides a good general assessment of the building condition, the results of this survey cannot be considered a warranty of the structural condition of the burn building. Furthermore, the survey results cannot be used, in themselves, as contract documents for repairs.

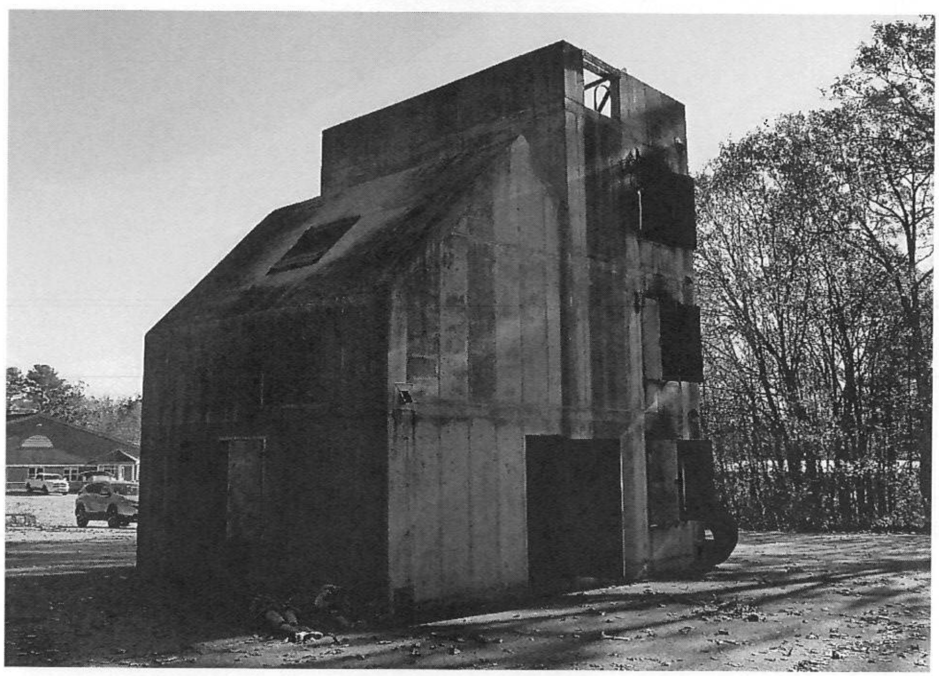
2. Burn Building Description

See Appendix 1 for approximate floor plans. For a glossary of all terms typed in *italics*, see Appendix 2.

The burn building is a three-story structure measuring approximately 21'-4" x 27'-1", with a total of 1,450 square feet of interior space. There are currently five burn rooms (rooms used for live fire training). The burn building is approximately 33 years old (constructed in 1989).



AB Perspective



CD Perspective

2.1 Structural Systems

The burn building structure is described in the table below. This description is based on the original drawings and observed conditions. The foundation was not excavated for observation. It is assumed that there are concrete *spread footings* below the exterior and interior concrete walls.

Element	Structural Materials	Non-Structural Materials
Exterior Walls	*Poured-in-place reinforced concrete* (bearing walls)	None
Interior Walls	Poured-in-place reinforced concrete (bearing walls)	None
Roof & Elevated Floors	Poured-in-place reinforced concrete	None
Ground Floor	None	Concrete *slab-on-grade*
Interior Stairs	Poured-in-place reinforced concrete	Steel guardrails anchored to concrete stair treads
Balconies	*Structural steel* framing supporting steel grating planks	Steel guardrails welded to steel framing and anchored to exterior concrete wall.

2.2 Non-Structural Features

The non-structural features are described in the table below.

Element	Description
Exterior & Interior Doors	Hollow metal doors and frames
Windows	Steel plate shutters (double swing) with latch and slide bolt
Roof Guardrails	Poured-in-place reinforced concrete parapets.
Roof Hatches	Steel plate hatch and wood-covered roof hatch

2.3 Use of Facility, Based on Interview with Facility Personnel

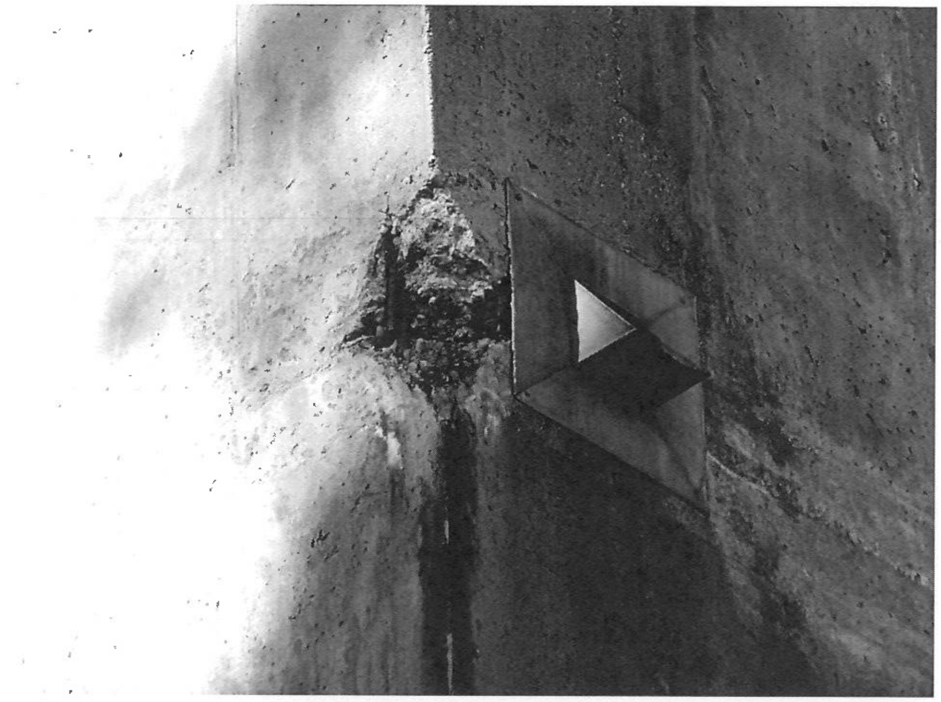
The following table describes the general use of this burn building, as provided by personnel from the facility. The information provided in this table gives an indication of the general care and condition of the burn building. Typically, one can expect to observe more damage in the building if there are one or more of the following: higher temperatures, frequent training evolutions, misuse, no thermal protection, and no routine maintenance.

Item	Information Provided by Chief Mark Nelson
Personnel that use the burn building	Milford Fire Department and surrounding district fire departments, as far out as Framingham, as well as the Massachusetts Fire Academy (MFA).
Degree of supervision	Fire departments using the building have their own certified safety personnel and follow the Milford F.D. burn protocol.
Number of live fire training days (days during which at least one fire was set) per year in this burn building	4 times per year for Milford F.D. 20 total including surrounding users.
Temperature range during training	Unknown.
Typical fuel used for one evolution	1 pallet and 1 bale of straw.
Damage to the structure that has either changed training routine or raised concerns about safety	Spall at exterior (AB corner) of the building. Live fire training suspended in June 2022.
Past repairs and renovations	MFA made repairs to shutters and doors, as well as added a stainless-steel cover for third floor roof hatch.
Maintenance history	None.
Planned changes for the future	None.
Other information	None.

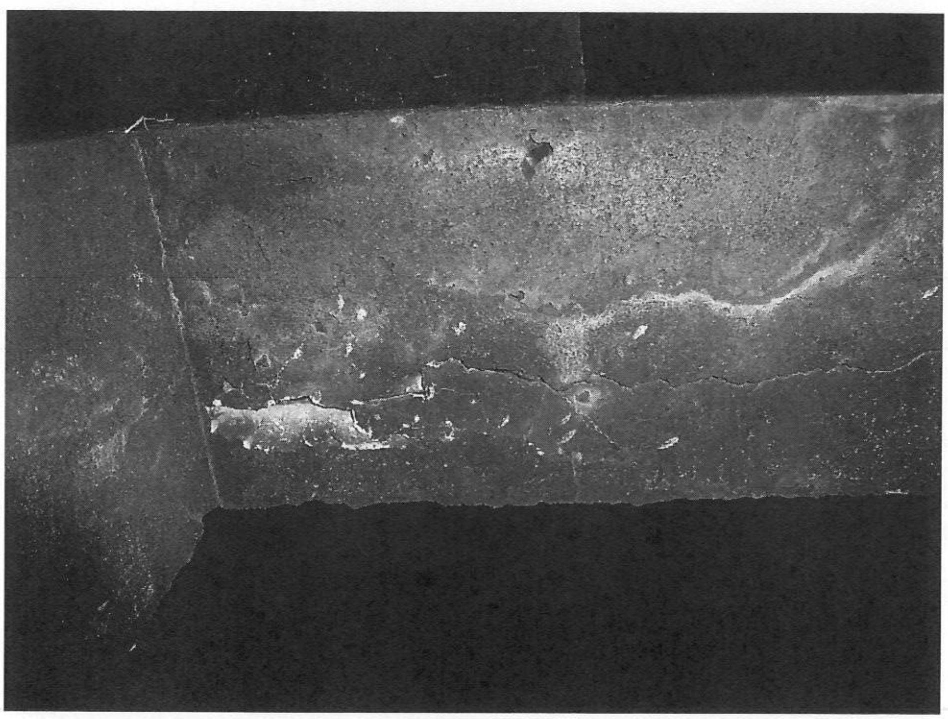
3. Structural Observations and Recommended Actions

The following structural defects were observed. Recommended actions for repairing the defects are provided in the following table.

Item	Observations and Recommended Actions
Concrete Walls (Items A, C, D, F, G, 4, 7, and 11 in Appendix 1)	Observations: Minor *cracks* and *crazing*, likely due to a combination of concrete shrinkage during the initial curing, thermal expansion and contraction during live fire training, and exposure to weather. The cracks and crazing do not appear to be a structural concern at this time but could widen with time due to exposure. There are a few areas of *efflorescence* at the A elevation that appear to occur at cold joints, indicating that moisture is passing through and/or gathering at the surface of the joints. These areas do not appear to be a structural concern at this time. There are moderate to severe *spalls* with exposed, corroded reinforcing at the exterior AB and BC corners of the structure, as well as at the exterior B elevation. There are moderate *cracks and spalls* with exposed reinforcing and *efflorescence* at the door lintel between Rooms 200 and 201. It appears that the concrete was not properly consolidated when poured, leaving some voids in the exposed concrete walls. It also appears that some reinforcing bars did not have proper concrete cover when the walls were poured, causing the bars to become exposed within shallow spalls. Recommended Actions: Patch all interior and exterior wall spalls and delaminations, including at the door lintel between Rooms 200 and 201. Remove loose concrete and remove corrosion from any exposed reinforcing bars. Remove concrete around exposed bars by a minimum of 1". Replace any reinforcing bars that have lost more than 15% of their cross-sectional area. Patch spalls with a high-strength, high-bond-strength, non-shrink patch material manufactured by Sika Corporation, Euclid Chemical Company, or other equivalent manufacturer that is suitable for exterior vertical applications. Follow manufacturer's instructions for preparing surface and mixing, placing, and curing patch material.



Spall at AB corner of building with exposed reinforcing (second floor).

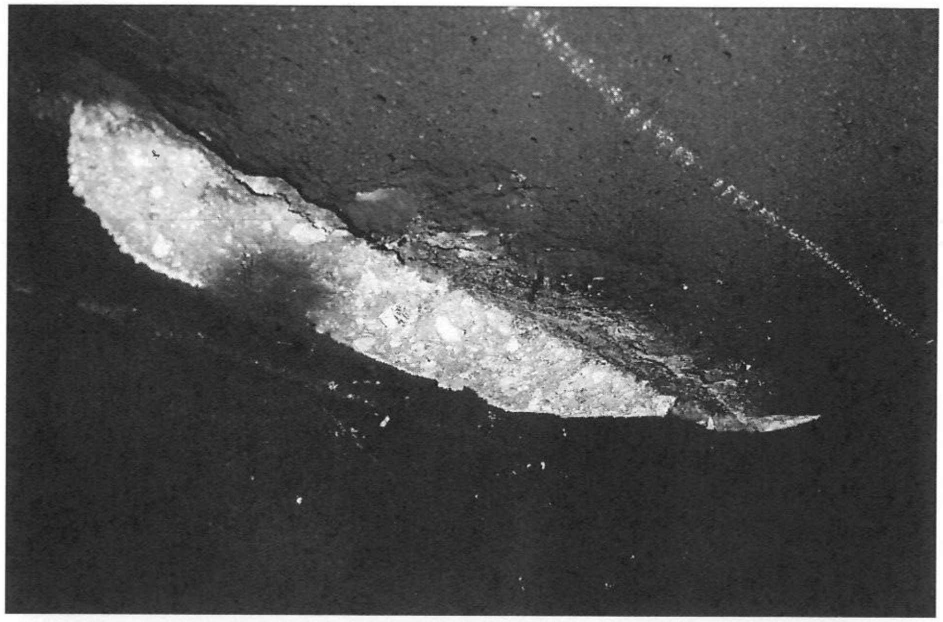


Cracks and exposed reinforcing in lintel over doorway between Rooms 200 and 201.

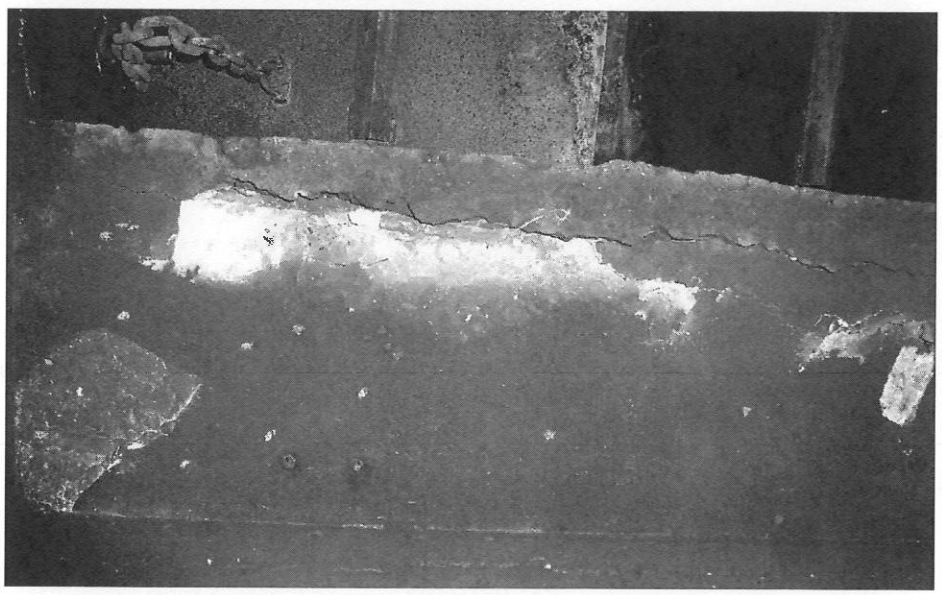
Item	Observations and Recommended Actions
Concrete Floor and Roof Slabs (Items 1, 3, 4, 5, 8, 9, and 14 in Appendix 1)	Observations: Minor *cracks, spalls,* and *delaminations* in the top surfaces of the slab-on-grade, and the top and bottom surfaces of the second and third floor slabs. This damage was likely caused by concrete shrinkage during the initial curing (cracks only) and high temperatures and flame impingement on the exposed floor slabs (cracks, spalls, and delaminations). The spalls and delaminations are shallow and do not appear to be as deep as the reinforcing layers. Some of the delaminations appear to be located at areas of previously-patched concrete. The spalls and delaminations do not significantly affect the capacity of the slabs and do not appear to allow moisture to penetrate into the concrete surface. However, a few of the spalls are deep enough to require repair to remove areas where water collects and to provide a smooth surface, should fire brick be placed on the floors in the future. The cracks are typically narrow (less than 1/32") and do not appear to allow water to reach the reinforcing. In Room 300, there are severe *spalls, cracks* and *delaminations* surrounding the roof hatch opening. It appears that the concrete was not properly consolidated when poured, leaving some voids in the exposed concrete slabs. It also appears that some reinforcing bars did not have proper concrete cover when the slabs were poured, causing the bars to become exposed within shallow spalls. Recommended Actions: Patch spalls in the tops of the slabs in Rooms 100 and 101, where fire brick might be placed on the floors in the future and where the spalls are rough on the hands and knees of personnel during training. Where spalls have been previously patched and the patch has worked loose, remove the old patch prior to providing a new patch. Patch spalls at the underside of the roof slab (ceiling of Room 300). For all spall/delamination repairs, remove loose concrete and remove corrosion from any exposed reinforcing bars. Remove concrete around exposed bars

Item	Observations and Recommended Actions
Concrete Floor and Roof Slabs (Items 1, 3, 4, 5, 8, 9, and 14 in Appendix 1) (Continued)	by a minimum of 1". Replace any reinforcing bars that have lost more than 15% of their cross-sectional area. Patch spalls with a high-strength, high-bond-strength, non-shrink patch material manufactured by Sika Corporation, Euclid Chemical Company, or other equivalent manufacturer that is suitable for exterior horizontal (at tops of slabs) and overhead (at bottoms of slabs) applications. Follow manufacturer's instructions for preparing surface and mixing, placing, and curing patch material. Provide fire brick on the floor for the extents of Rooms 100 and 101, and burn only on burn racks that do not allow burning fuel, coals, ash, or embers to fall to / rest upon the floor in order to reduce the risk of new damage and patches failing if burning is going to continue in these rooms.

Spalled patches at top of slab-on-grade in Room 101.



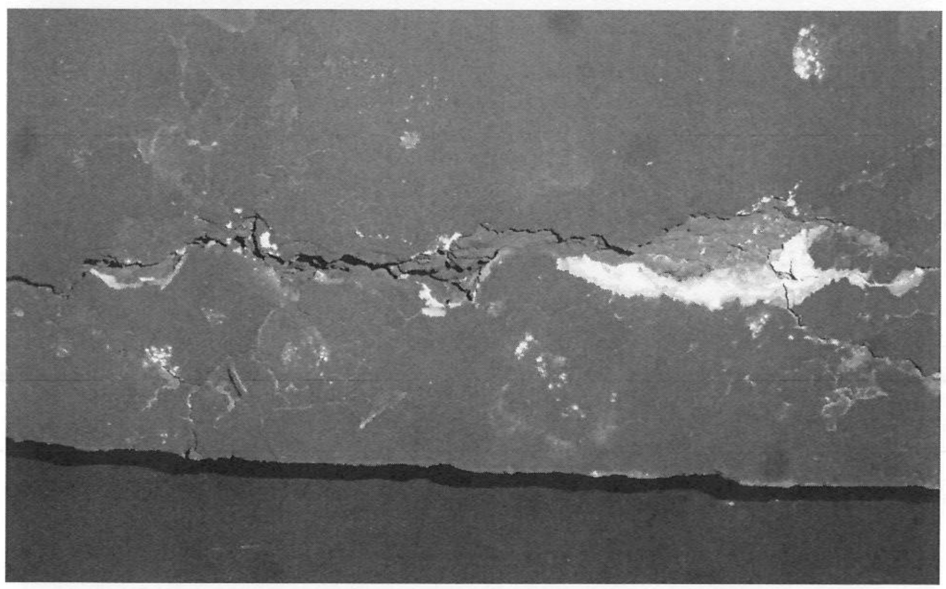
Spall with exposed, corroded rebar at the ceiling of Room 300.



Spall with exposed, corroded rebar and delaminated concrete at the ceiling of Room 300 adjacent to the roof opening.

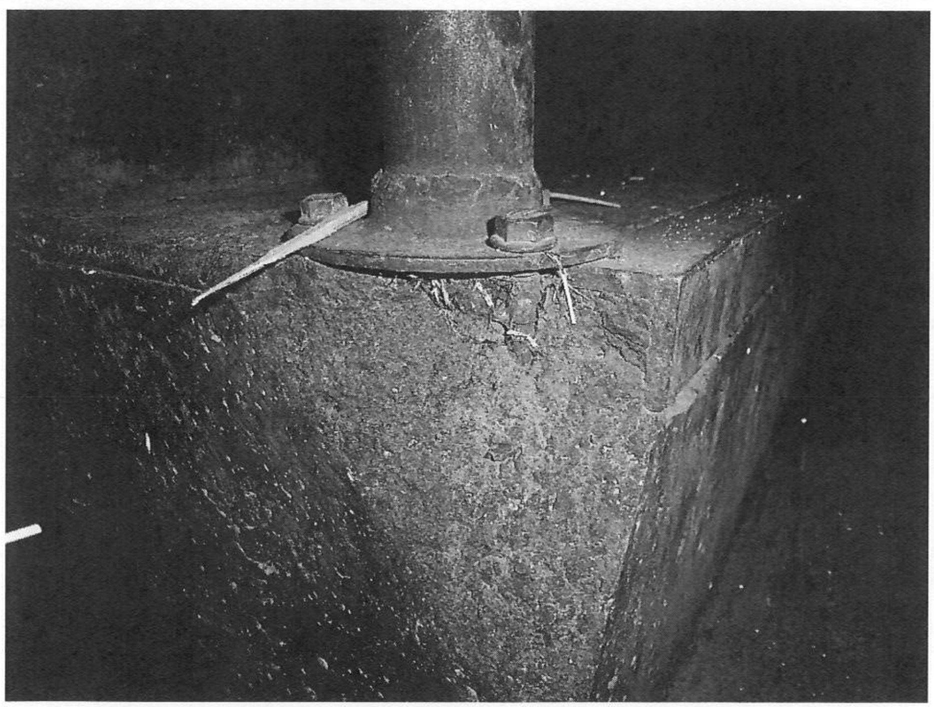
Item	Observations and Recommended Actions
Concrete Beams (Items 14 and 15 in Appendix 1)	<u>Observations:</u> There are minor *cracks* and *efflorescence*, on the beams below the second floor slab, likely due to a combination of concrete shrinkage during the initial curing, thermal expansion and contraction during live fire training, and exposure to weather. The cracks do not appear to be a structural concern at this time but could gradually widen with time due to exposure. There are moderate to severe *cracks*, *spalls*, and *delaminations* on the beams below the sloped concrete roof and below the high roof (ceiling of Room 300), adjacent to the roof chopout opening. <u>Recommended Actions:</u> Epoxy inject cracks that are wider than 1/16" and narrower than 1/8" with Sikadur 52 or an equivalent product. For beams with spalls, delaminations, and cracks wider than 1/8", remove loose concrete and remove corrosion from any exposed reinforcing bars. Remove concrete around exposed bars by a minimum of 1". Replace any reinforcing bars that have lost more than 15% of their cross-sectional area. Patch spalls with a high-strength, high-bond-strength, non-shrink patch material manufactured by Sika Corporation, Euclid Chemical Company, or other equivalent manufacturer that is suitable for exterior overhead and vertical applications, or form-and-pour patch material, to patch and, if necessary, re-build beam soffits. Follow manufacturer's instructions for preparing surface and mixing, placing, and curing patch material. If significant volumes of concrete are delaminated/spalled, it is possible that the beam(s) will have to be demolished and re-poured with new cast-in-place concrete instead of patching.

Severely delaminated and cracked beam at underside of high roof slab.



Severely delaminated and cracked beam at underside of high roof slab.

Item	Observations and Recommended Actions
Concrete Stair Slabs (Item 2 in Appendix 1)	Observations: Moderate spalls at the corners of several treads in both flights of stairs (first to second floor and second to third floor). Minor cracks and delaminations at the underside of the concrete stair slab from first to second floor. Recommended Actions: Patch spalls at the edges of the stair treads. Remove loose concrete and remove corrosion from any exposed reinforcing bars. Remove concrete around exposed bars by a minimum of 1". Replace any reinforcing bars that have lost more than 15% of their cross-sectional area. Patch spalls with a high-strength, high-bond-strength, non-shrink patch material manufactured by Sika Corporation, Euclid Chemical Company, or other equivalent manufacturer that is suitable for exterior vertical and overhead applications. Follow manufacturer's instructions for preparing surface and mixing, placing, and curing patch material.



Spall at edge of concrete stair tread.

4. Non-Structural Observations and Recommended Actions

The following non-structural defects were observed. Recommended actions for repairing the defects are provided in the following table.

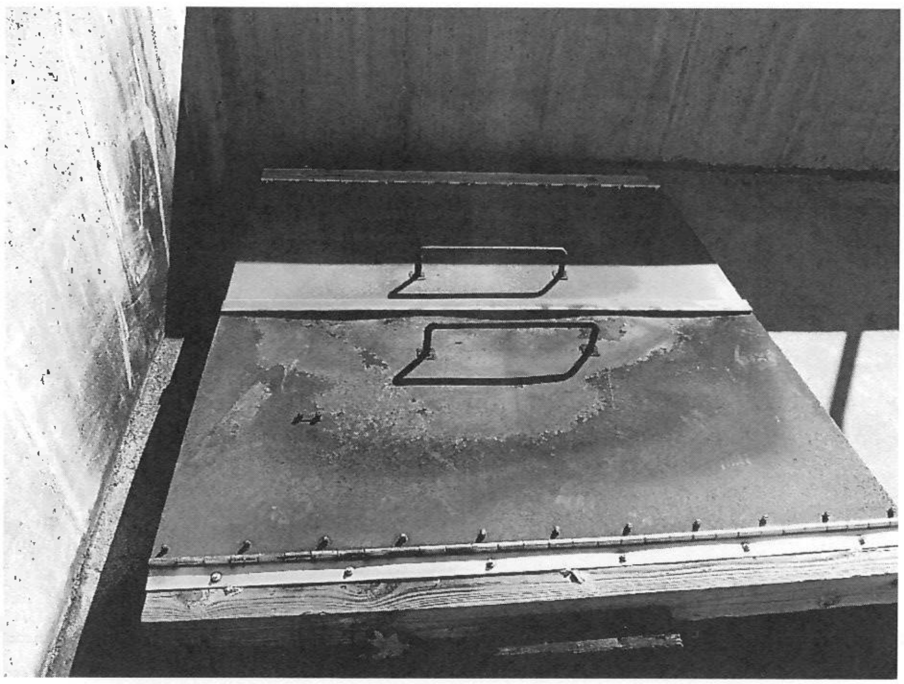
Item	Observations and Recommended Actions
Exterior and Interior Doors & Frames (Items I and 13 in Appendix 1)	Observations: The two exterior doors and frames to the second and third floor balconies are severely corroded. The door latch into Room 101 from the exterior sticks and is difficult to operate. Recommended Actions: Remove the corroded doors and frames and replace with new doors in Rooms 200 and 300. Replace the sticking door handle at the exterior door into Room 101.

Severely corroded door frame in Room 300.

Item	Observations and Recommended Actions
Windows (Item H in Appendix 1)	Observations: There is minor corrosion on all of the shutter plates. The latch handle on the right leaf (from the exterior) of the shutter in Room 100 is broken. Recommended Actions: Replace the broken handle at the shutter in Room 100. No repair is required for the minor corrosion on the shutter plates.

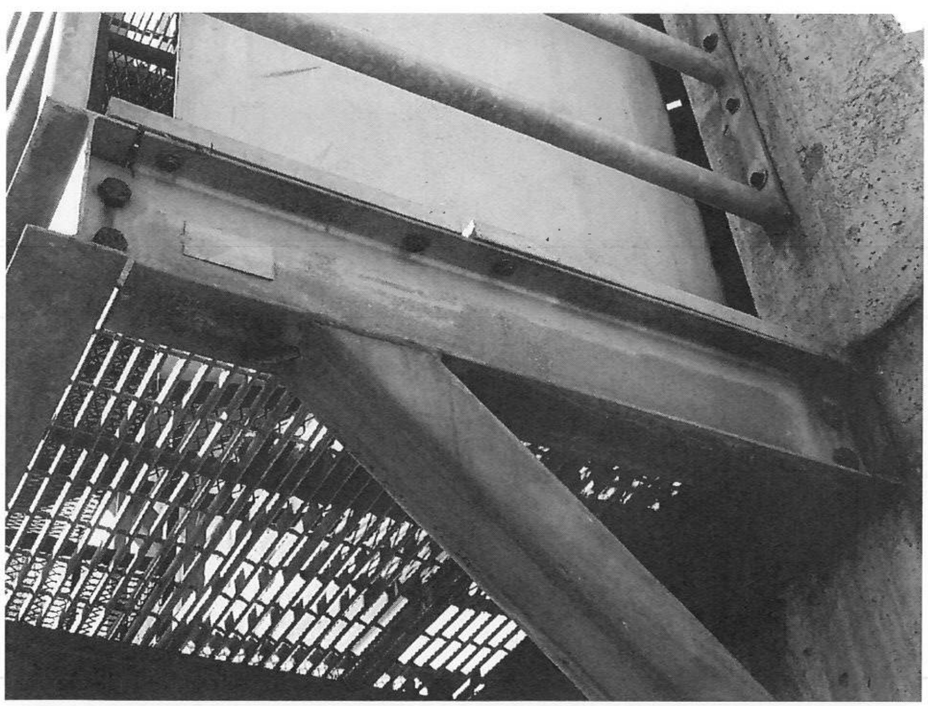
Broken shutter handle.

Item	Observations and Recommended Actions
Roof Access Hatches	Observations: The steel cover plates and frames at the roof access hatches are slightly warped and moderately corroded. Recommended Actions: If desired, remove corrosion and paint steel items with two coasts of a rust-inhibiting, exterior-quality paint. Otherwise, no additional action is recommended at this time.



Warped and corroded roof chopout cover plates.

Item	Observations and Recommended Actions
Exterior Steel Balconies (Items K and L in Appendix 1)	Observations: There is minor corrosion on the exterior steel balconies, railings, and connections. The galvanizing vent holes at the steel tube kickers have not been plugged, which could allow water to get into the tubes and freeze during winter months, which could cause the steel to expand and crack. The holes allow nesting insects and a yellow jacket nest was visible. Recommended Actions: If desired, remove all corrosion and touch up galvanizing with two coats of galvanizing repair paint. Plug all vent holes by either (A) hammering in a zinc galvanizing vent hole plug by Bruce Reichelt Enterprises, grind it smooth, and touch up with galvanizing repair paint or (B) plug welding the vent holes, grinding the welds smooth, and touching up with galvanizing repair paint. Drill a 1/2" diameter weep hole at the bottom of each tube kicker, 1" above the diagonal from the wall connection, to allow water to drain. Touch up the hole with galvanizing repair paint.

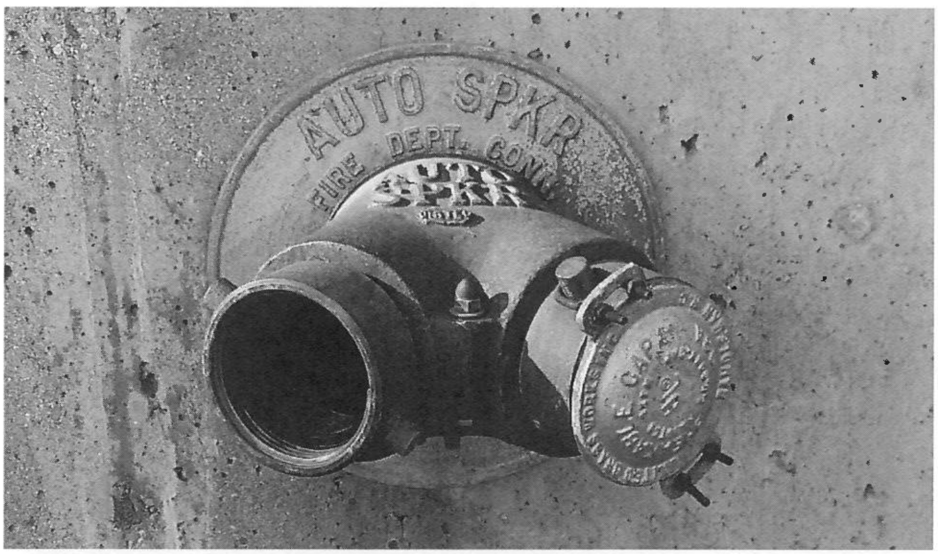


Minor corrosion on balcony steel framing, railings, and connections.

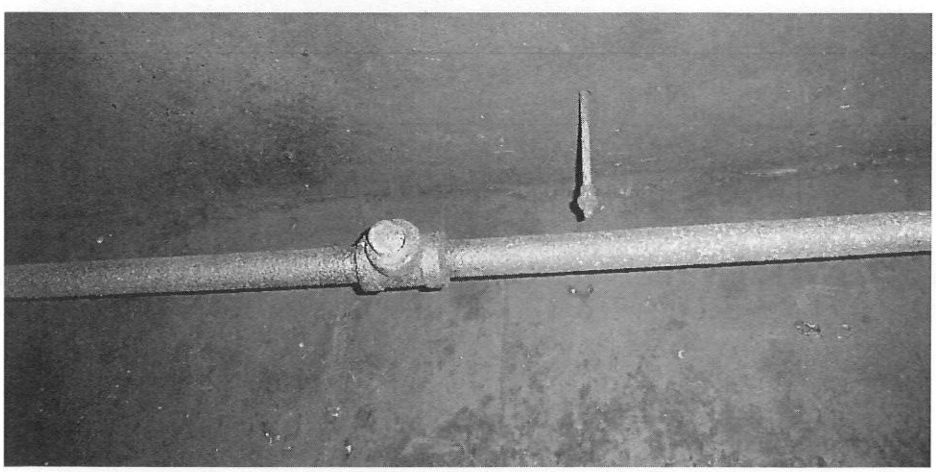
Item	Observations and Recommended Actions
Scuppers (Item B in Appendix 1)	Observations: The sheet steel at the majority of the scupper openings is severely damaged. Recommended Actions: Remove the damaged sheet steel, especially at the ground floor level so it doesn't snag gear or hoses. If desired, replace the sheet steel with a thicker gauge steel or steel plate to better withstand impact and debris.

Damaged sheet steel at ground floor scupper opening.

Item	Observations and Recommended Actions
F.D.C. and sprinkler pipes (Items J and 6 in Appendix 1)	Observations: The F.D.C. is missing the left valve cap. The sprinkler pipes and hangers throughout the building are broken and/or missing. Recommended Actions: Replace the missing F.D.C. valve cap. If desired, replace the broken/missing sprinkler pipes and hangers.



Missing valve cap at F.D.C.



Broken sprinkler pipes/hangers.

4.1 Recommended Actions for Thermal Linings

In burn rooms, unprotected structural elements will be exposed to high temperatures that will likely cause structural damage. Similarly, the recommended structural repairs can fail as early as the first burn evolution if no thermal protection is provided. Therefore, the building requires a thermal lining to reduce the likelihood of future structural damage to the building and repairs. See Appendix 3 for descriptions of thermal lining products.

The following recommendations are provided. These recommendations are based on types of fuels burned, number of training days per year, and degree of damage observed.

All of these options add weight to the structure. Before adding any thermal linings, the existing structural elements (slabs, beams, walls, and foundations) will need to be analyzed to ensure they have sufficient capacity to support the additional weight of thermal linings. This evaluation is outside the scope of this report.

Thermal Linings at Ceilings:

Install a thermal lining to cover the entire ceiling in each burn room. There are two types of thermal linings that could be used at the ceiling (see Appendix 3 for more information):

1. High Temperature Linings, System 203.

2. Exposed insulation boards, specifically Padgenite Super HD or Thermablast.

Based on references, HTL System 203 would likely have less maintenance requirements than Padgenite Super HD / Thermablast but the latter should be considered if it creates an initial cost savings of 20% or more. Though exposed to higher temperatures, ceiling thermal linings are usually less likely to fail from impact loads, compared to wall linings. Therefore, both options should be priced. As with the wall linings, we recommend obtaining prices that include all general conditions, materials, labor, equipment, overhead, profit, and any other markups for installation and clean up.

Thermal Linings at Beams:

Install a thermal lining to cover the entire beam in each burn room. There are two types of thermal linings that could be used at the beams (see Thermal Linings at Ceilings above).

Thermal Linings at Walls:

The interior walls are in relatively good condition. However, if burns are conducted near unprotected walls, the concrete would be expected to continue to crack and deteriorate. Although such deterioration could be gradual, allowing structural *bearing walls* to deteriorate in this manner is not recommended.

As a result, it is recommended that sacrificial masonry, either *fire brick* or hollow *CMU*, be located at each burn corner for a minimum distance of 8'0" from the corner in each direction (or at all walls for rooms where the fires are placed at multiple locations within the room). The sacrificial masonry should be tied back to the structural wall and allowed to "float" relative to the structural wall.

Note that the sacrificial masonry will crack and deteriorate when exposed to fire and thermal shock, starting with the first training evolution. However, fire brick or CMU at burn areas is usually stable and effective for at least 5 to 10 years, despite cracking and deterioration. The lining should be checked before each training day to ensure that it is stable and not pulling away from the structural backing walls.

An option to the sacrificial masonry, bringing a higher initial cost but less long-term maintenance, is High Temperature Linings System 203. We recommend obtaining a quote for HTL System 203 as well as fire brick or CMU built (with mortar and tie backs) against the bearing walls as sacrificial masonry. When comparing costs, it is best to obtain quotes that include all general conditions, materials, labor, equipment, overhead, profit, and any other markups for installation and clean up.

It is possible to use Padgenite Super HD or Thermablast at the walls, though this product's track record indicates it is more susceptible to damage in Class A burn buildings when on walls due to higher frequency of impact from tools, equipment, and high pressure hose streams.

Thermal Linings at Floors:

Install loose laid fire brick (tight together but no mortar) across the entire surface of each burn room. Even if fires are to be placed only in one burn corner in each room, the entire floor should be lined instead of the floor area just in the burn corner. Heat from the fire can bank down to the floor a considerable distance from the fire itself. If fire brick is located on the floor just at the burn corner, exposed concrete away from the fire could spall due to the banking heat. Therefore, lining the entire floor of each burn room is recommended. For long term maintenance, if any bricks become damaged to the point that the concrete floor becomes exposed, those bricks should be replaced.

Note that the recommended actions for structural and non-structural defects are intended to restore visibly deteriorated areas to good condition in order to prolong the life of the burn building. This does not guarantee the burn building will remain in good condition for any particular period of time. Even if thermal linings are installed, repetitive live fire training will continue to deteriorate the burn building after the following recommendations are implemented, but to a lesser degree than in the past. Nevertheless, repairs and maintenance for structural elements, non-structural features, and linings can be expected in the future and should be included in budget planning.

5. Summary and Conclusions

In general, the burn building is in fair structural condition and requires repairs and renovations to allow training (cold or live fire) in the structure.

In order to continue to use this structure as a cold training facility (no live fire training):

- Remove all loose concrete from the beams and underside of slab surrounding the roof chopout opening at the third floor ceiling.
- Patch all spalls as described in the body of the report.

In order to use this structure as a live fire training structure:

- Repair the spalls at the top of the slab-on-grade, tops and bottoms of elevated floor slabs and roofs, and concrete stair slabs.
- Repair the spalls at the interior and exterior concrete walls.
- Repair the spalls, delaminations, and cracks in the beams surrounding the roof chopout opening at the third floor ceiling as well as the beam below the pitched roof.
- Install thermal linings on burn room ceilings., beams, and walls.
- Install thermal linings (fire brick) on floors in burn corners.
- Burn only on burn racks that do not allow burning fuel, coals, ash, or embers to fall to / rest upon the floor in order to reduce the risk of new damage and patches failing.

Non-structural repairs that are recommended include:

- Replace the doors and frames in Rooms 200 and 300.
- Replace the broken handle at the shutter in Room 100.
- If desired, remove corrosion from shutters, roof chopout cover plates, exterior steel balcony framing, guardrails, and connections and touch up galvanizing with two coats of galvanizing repair paint.
- Plug vent holes in HSS kickers at second and third floor balconies.
- Replace sheet steel at ground floor scuppers.
- Provide cap at F.D.C. valve.
- Replace broken sprinkler pipes and pipe hangers.

Note that this survey provides a general assessment of the condition of the burn building on the date of the survey. Live fire training and continued exposure to the elements will further degrade the burn building and its components. The condition of the burn building will change with the first live fire training evolution conducted after the survey. Therefore, there is no guarantee that the burn building will remain in its current condition for any length of time. If live fire training evolutions are conducted in the burn building before the recommended repairs and renovations are performed, or if a year elapses with no live fire training in the burn building before the recommended repairs and renovations are performed, then the findings of this report may become invalid and may require additional survey work.

Appendix 1
Approximate Floor Plans and Field Notes

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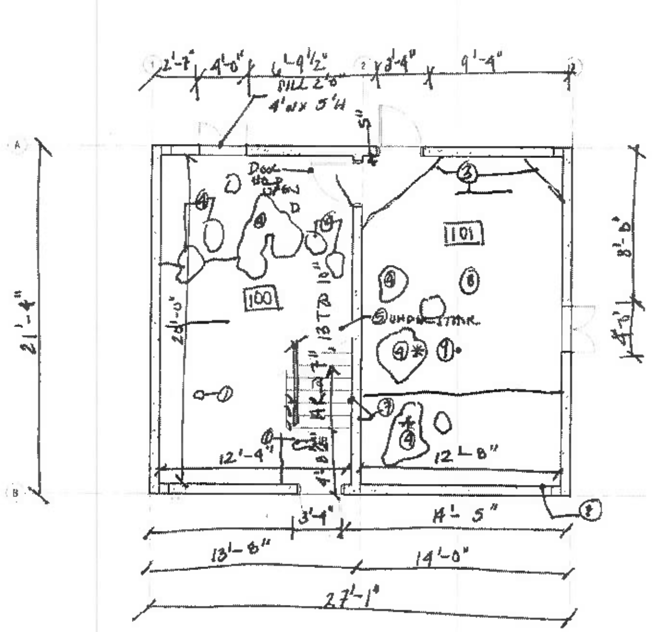
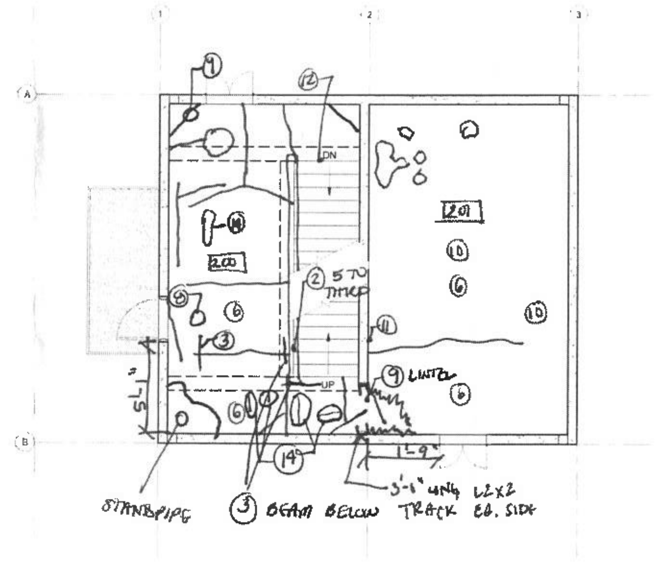


FIRST FLOOR PLAN
BB100 SCALE 1/4" = 1'-0"



SECOND FLOOR PLAN
BB100 SCALE 1/4" = 1'-0"

① MINOR SPALL < 1/4" D
② SPALL AT STAIR EDGE (? FIRST FLOOR)
③ MINOR CEILING CRACK (W/EFFLORESENCE)
④ MOD SPALL 1/2" DEEP (* DELAM/SPALLED PATCH)
⑤ MINOR CRACK – NO REPAIR
⑥ BROKEN SPRINKLER PIPE / HANGER
⑦ MINOR WALL SPALL – NO REPAIR
⑧ MINOR SPALLING (MIDDLE OF CEILING)
⑨ SPALL W/ EXPOSED WOOD CHAIR & REBAR
⑩ PONDING WATER
⑪ EFFLORESENCE

⑫ TOP STEP TREAD PL. MISSING (2) SCREWS
⑬ SEVERELY CORRODED DOOR – REPLACE
⑭ DELAMINATION
⑮ MOD CRACK IN BEAM

BLACK ARE DEFECTS AT CEILING ABOVE

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Architect

Project Title

**Milford, MA
Live Fire Training
Structural Inspection**
EL&M NO 22049

Owner

Rev. Date Description Approved

Sheet Title

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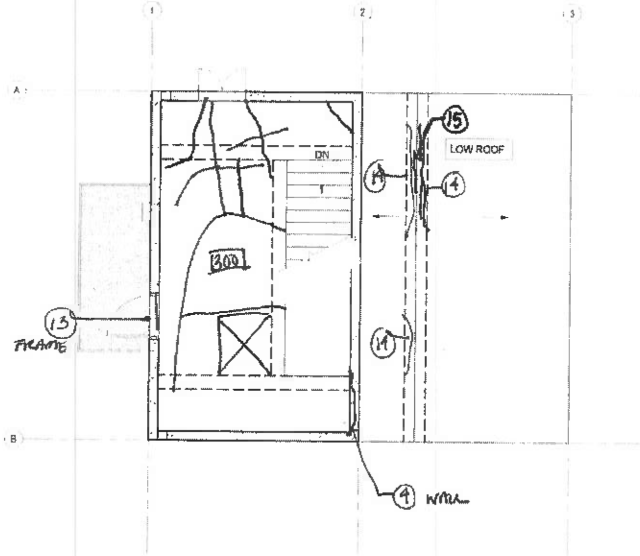
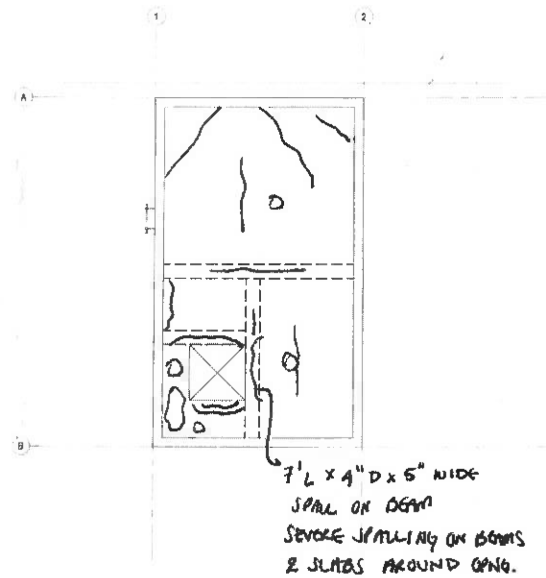


1 THIRD FLOOR/LOW ROOF PLAN
BB101 SCALE 1/4" = 1'-0"



2 HIGH ROOF PLAN
BB101 SCALE 1/4" = 1'-0"

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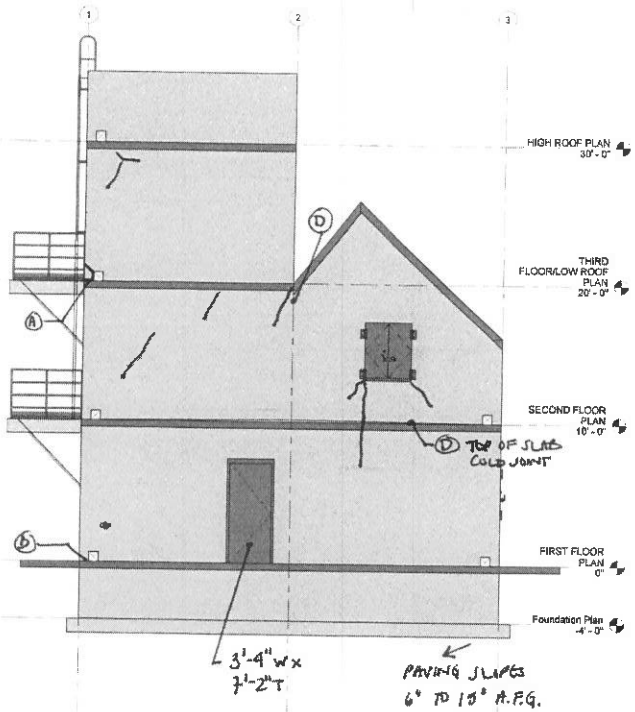
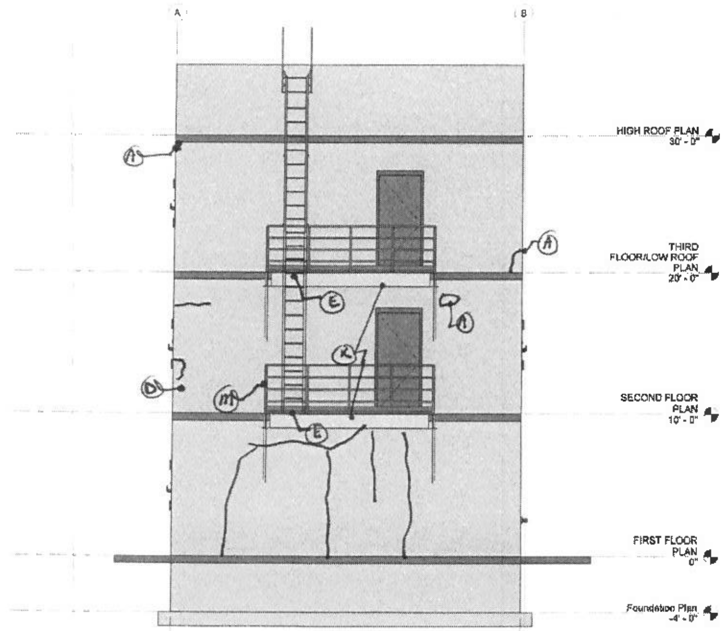


1 A ELEVATION
BB103 SCALE 1/4" = 1'-0"



2 B ELEVATION
BB103 SCALE 1/4" = 1'-0"

- (A) SPALL W/ EXPOSED REBAR
- (B) WARPED SCUPPER EXTENSIONS (ALL)
- (C) HAIRLINE CRACK < 1/8"
- (D) EFFLORESENCE
- (E) MISSING BOLTS
- (F) CRAZING
- (G) DELAM - PEALING SEALER
- (H) SHUTTER HANDLE BROKEN
- (I) DOOR STICKS -
- (J) MISSING COVER ON PVC
- (K) MINOR CORROSION ON SHUTTERS & STEEL BALCONY FRAMING
- (L) OPEN GALV. VENT HOLES - INSECTS
- (M) SPALL AT GUARDRAIL ANCHOR

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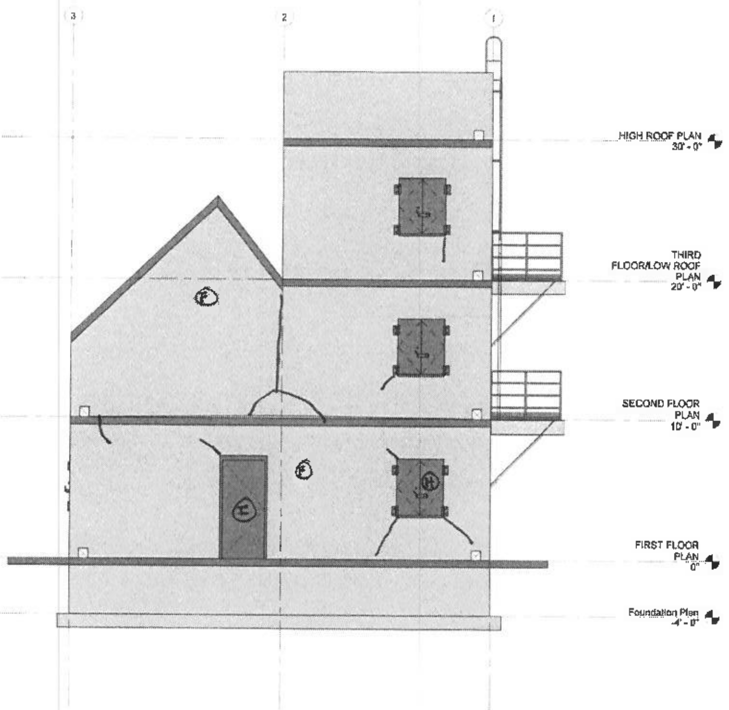
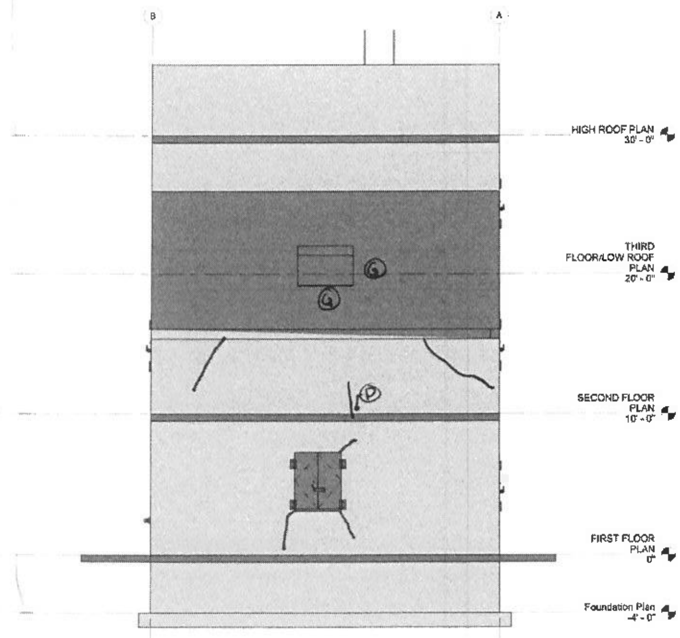


1 BB102 ~~A~~ C ELEVATION
SCALE 1/4" = 1'-0"



2 BB102 ~~B~~ D ELEVATION
SCALE 1/4" = 1'-0"

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Appendix 2
Glossary of Structural Terms

Glossary of Terms

Term	Definition
ACI 318	"Building Code Requirements for Reinforced Concrete", published by the American Concrete Institute (ACI). This concrete code is referenced by the Building Code and provides design standards for reinforced concrete construction.
ASTM	American Society for Testing and Materials. The standards written by ASTM are widely used in the construction and building design industry, and are referenced by the Building Codes.
Bearing wall	A structural wall which supports the roof and elevated floor structures.
Bond beam	A continuous horizontal masonry course, usually at or near a roof or floor elevation, that ties the building together around its perimeter. It can also serve to support roof or floor loads over *non-bearing walls* or wall openings. A *CMU* bond beam is typically constructed of U-shape block filled with *grout*, with continuous *reinforcing bars* running parallel to the course.
Calcium Aluminate Concrete	A special concrete product produced using calcium aluminate cement instead of standard portland cement. The aggregate can be either normal weight, lightweight, or calcium aluminate aggregates. The chemical composition of calcium aluminate concrete makes it more resistant to high temperatures and thermal shocks. It is less likely to spall or delaminate when first exposed to fires, compared to regular concrete made with portland cement. However, many older burn buildings with structural, reinforced, cast-in-place, calcium aluminate concrete slabs, beams, columns, and walls have large delaminations that are significant safety concerns. Calcium aluminate concrete is also known as "refractory concrete."

Cement Matrix Deterioration	Chemical breakdown of the cement paste in concrete or *CMU* due to high temperatures and flame impingement. This deterioration manifests itself as pitting, dusting, or eroding of the exposed concrete or CMU surface.
CMU	Concrete Masonry Unit, also referred to as concrete block, cinder block, or block. These blocks are made of concrete, are typically hollow but can be solid, and are typically 16" long x 8" high x a thickness of 6", 8", or 12" (nominal dimensions). CMU is typically defined by *ASTM* C-90.
Compression test (concrete)	Removing a cylindrical sample of existing, in-place concrete with a core drill, compressing the concrete sample in a machine until failure, and calculating the compressive strength of the sample from the measured test results. This test is significant because compressive strength is an important concrete quality. Test is defined by *ASTM* C-42.
Concrete fill	Non-structural, low-grade concrete placed on top of a structural element such as a structural concrete slab or *steel deck*. Typical uses for concrete fill include insulation, achieving roof slope, providing a smooth finish, and moisture protection for steel deck.
Concrete topping	Structural or non-structural concrete poured on top of a structural element, such as composite *steel deck* or *precast prestressed hollow core plank*, to provide a smooth finish and/or additional structural capacity.
Crack	An unintentional break in a building material, such as concrete or *CMU*, that can be through a partial depth or the entire depth of the material. In a burn building, there can be several causes of cracks, but the most common ones are (1) expansion and contraction of the concrete or CMU during heating and cooling causing excessive stress within the material, (2) shrinkage of the concrete during the original curing process (not related to fire training evolutions).
Crazing	Narrow, shallow surface cracks in concrete that separate the surface into small, irregularly shaped, contiguous areas.
Delamination	A separation along a plane, generally parallel to the concrete surface, causing the surface to become loose though still in place. In a wall, the separation is vertical. In a slab, the

	separation is horizontal. If the separation falls out or disintegrates, the area becomes a *spall.* In a burn building, delaminations usually occur because (1) moisture within the concrete changes to steam when exposed to high temperatures, and the steam pressure separates the concrete, or (2) fuel used to ignite the fires soaks into the concrete and burns when exposed to high temperatures, increasing internal pressure.
Discoloration	Concrete exposed to high temperatures changes from its typical gray color to a pinkish, salmon color (above 600° F), a white color (above 1,100° F), or a tan, or buff color (above 1,700° F).
Efflorescence	Deposits of salts that form on the surface of concrete, *CMU*, or brick as a result of evaporation of the water in which the salts were dissolved. Usually an indication that moisture is passing through the structural material.
Expansion joint	Intentional gap through the entire thickness of a building element, such as a wall or a slab, to allow for expansion and contraction of the element when it is exposed to temperature changes. Expansion joints can be built into the element during original construction, or can be cut into the element at a later time. In a burn building, expansion joints are most commonly found in walls, especially near the corners of exterior walls and at the intersection of an interior and exterior wall.
Fire brick	Masonry brick, usually made of *fire clay*, especially made to withstand the effects of high heat without fusion or softening.
Fire clay	A natural clay which does not fuse or soften when subjected to high temperature. Fire clay typically contains fewer metallic oxides than other natural clays.
Grout	For application in filling hollow cells of *CMU* walls: a fluid concrete mix that will flow freely into masonry joints and cells within a wall to fill all voids solid. For application in filling a crack in a masonry wall or a gap between two elements: a stiff concrete mix that resembles masonry mortar and is troweled into a crack or gap to seal the void.

Hollow core plank	*Precast concrete* structural slab element reinforced with prestressed steel cables. Typical plank size is 2'-0" wide x 6" or 8" thick x required length up to approximately 35'-0". Circular voids, approximately 4" to 5" in diameter, run the entire length of the plank to reduce the weight of the slab. After curing, planks are transported, lifted into place, and anchored to supporting beams or walls. A structural *concrete topping* is often placed on top of the planks after erection.
Lightgage metal joist	A horizontal structural framing element (joist) made of thin steel material, typically 12 gage or thinner. Most common cross section is C-shaped.
Lightgage metal stud	A vertical structural framing element (stud) made of thin steel material, typically 12 gage or thinner. Most common cross section is C-shaped.
Lintel	A horizontal beam placed across the top of a door or window opening to support the wall immediately above the opening. Lintels in a burn building are typically fabricated out of *precast concrete* or a reinforced masonry course. Lintels can also be fabricated out of steel angles, steel wide flange section (I-beam), stone, or wood.
Non-bearing wall	A non-structural wall, also called a partition, that divides the space into rooms but does not support floor or roof structures, or any other ceiling loads.
Petrographic analysis (concrete)	Removing a cylindrical sample of existing, in-place concrete with a core drill, slicing the core vertically and horizontally, and analyzing the core along the sliced faces. This test determines, among other properties, the physical composition, degree of cracking, and degree of cement paste degradation within the sampled core. Test is defined by *ASTM* C-856.
Pilaster	A rectangular column attached to a wall, so that the face of the column projects out from the face of the wall.
Poured-in-place reinforced concrete	Concrete reinforced with steel bars that is poured into forms and cured at its final location. Once the wet concrete cures, the forms are removed but the concrete is not relocated.

Pre-engineered metal building	A building constructed of standardized steel roof and wall assemblies, that is engineered by the manufacturer for typical column bay dimensions.
Pre-engineered wood truss	Truss element, typically fabricated out of conventional 2x lumber and steel nail plates, that is engineered by the manufacturer for given spans, configurations, and load requirements.
Precast concrete	Concrete reinforced with steel bars that is poured into forms and cured at a location other than its final location. Once the wet concrete cures, the forms are removed and the concrete element is transported, lifted, and anchored into its final location.
Precast prestressed hollow core concrete plank	See *hollow core plank.*
Pressure injection (for *crack* repair)	A concrete *crack* repair method usually made with epoxy. The typical repair sequence is to seal the exposed faces of the crack(s) with epoxy, drill small holes into the concrete at the cracks, and inject epoxy under pressure to completely fill the crack. If the shiny epoxy appearance at the face of the crack is undesirable, the epoxy that was applied to initially seal the exposed crack faces can be ground away to bare concrete.
Prestressed concrete	Concrete element reinforced with steel cable that is mechanically tensioned.
Prestressed concrete double tee	*Precast concrete* structural slab element, reinforced with prestressed steel cables, with a cross-section in the shape of a double tee (TT). After curing, the sections are transported, lifted into place, and anchored to supporting beams or walls.
Prism test (masonry)	Removal of a piece of masonry (CMU) wall at the mortar joints, typically 2'-0" height x 1'-6" length x wall thickness, compressing the sample in a machine until failure, and calculating the compressive strength of the sample from the measured test results. This test is significant because compressive strength of the masonry wall assembly (f'm) is an important masonry quality. Test is defined by *ASTM* E-447.

Refractory concrete	A special concrete product produced using calcium aluminate cement instead of standard portland cement. The aggregate can be either normal weight, lightweight, or calcium aluminate aggregates. The chemical composition of refractory concrete makes it more resistant to high temperatures and thermal shocks. It is less likely to spall or delaminate when first exposed to fires, compared to regular concrete made with portland cement. However, many older burn buildings with structural, reinforced, cast-in-place, refractory concrete slabs, beams, columns, and walls have large delaminations that are significant safety concerns. Refractory concrete is also known as "calcium aluminate concrete."
Reinforcing bar	A round, steel bar used to reinforce concrete or *CMU*. Typical bar diameters range between 3/8" and 2-1/4". Reinforcing bars are typically defined by *ASTM* A-615.
Repoint	To remove and replace mortar in the joints of a masonry wall.
Scaling	Small, shallow pits in a concrete surface, usually grouped in a small area. Scaling does not expose reinforcing and is smaller and shallower than a *spall*.
Slab-on-grade	A concrete slab element poured on, and permanently supported by, the ground.
Spall	An area in a concrete surface in which the outer surface has separated from the base concrete element and disintegrated, leaving a shallow crater in the surface. Spalls can occur on a vertical wall surface, a horizontal floor slab surface, or an overhead ceiling slab surface. In a burn building, spalls usually occur because (1) moisture within the concrete changes to steam when exposed to high temperatures, and the steam pressure separates the concrete, or (2) fuel used to ignite the fires soaks into the concrete and burns when exposed to high temperatures, increasing internal pressure.
Spread footing	A concrete foundation for a wall or column. The dimensions of a spread footing are larger than those of the supported element, so as to distribute the load across a larger area of supporting soil and reduce settlement. Also called a "footing" or a "footer".

Steel deck	Corrugated sheets fabricated from thin steel, typically 16 gage or thinner, that can be used in floor and roof construction. Steel deck is typically used in one of three ways: (1) as a structural support for a non-structural *concrete fill*; (2) as a non-structural element used only as a form for a structural concrete slab; (3) as a structural element that acts compositely with a structural *concrete topping.*
Steel joist	A horizontal structural framing element (joist) made of *structural steel* material that is a parallel-chord truss. Typically, the top and bottom chords of the joists are steel angles or bars, and the webs are steel bars.
Structural steel	Steel elements fabricated in shapes, such as wide flanges (I-beams), channels, angles, pipes, tubes, bars, and plates. These can be used as structural or non-structural elements.
Tensile test (reinforcing)	Removing a length of steel *reinforcing bar* from an existing, in-place concrete element, pulling the reinforcing sample in a machine until failure, and calculating the tensile strength of the sample from the measured test results. This test is significant because tensile strength is an important reinforcing quality. Test is defined by *ASTM* A-370.
Tensile test (structural steel)	Removing a length of existing *structural steel,* pulling the reinforcing sample in a machine until failure, and calculating the tensile strength of the sample from the measured test results. This test is significant because tensile strength is an important quality in structural steel. Test is defined by *ASTM* A-370.
Welded wire fabric	Reinforcing mesh fabricated from two layers of thin steel wires welded together, with the top layer perpendicular to the bottom layer. Wire spacing in each layer is typically 4" or 6".

Appendix 3
Thermal Linings

Thermal Linings

1. Background

Fire training evolutions within a fire training burn building apply extreme temperatures and thermal shocks to the burn building structure. Fires fueled by Class A materials can apply temperatures approaching 2,000° F to portions of the structure. When the fire is extinguished, the heated structure is exposed to water that is approximately 60° F, causing a severe thermal shock. Standard structural materials used to construct the burn building are damaged in such conditions, especially when subjected to hundreds of training evolutions during the life of the building.

Structural concrete begins to deteriorate at temperatures as low as 550° F. Structural and reinforcing steel begin to approach critical temperature at 1,000° F. Special precautions can be employed to try to reduce the temperatures in burn rooms. Examples include using small fires, supervision to ensure small fires, a temperature monitoring system to track temperature levels during the evolutions, and a procedure for cooling rooms when temperatures approach critical levels. Nevertheless, temperatures applied to the bare structure usually exceed critical levels during routine training. As a result, thermal linings have been used in many burn buildings in an attempt to protect the building structure and prolong the life of the building.

There are many thermal linings available on the market. During dozens of burn building surveys throughout several states, Elliott, LeBoeuf & McElwain (EL&M) has observed numerous lining systems. Fire academy personnel have provided us with their insights about the thermal linings at their academies, including if they like the lining, how well it works, and their lining costs. EL&M has also called lining manufacturers to learn what they say about their products. Furthermore, we have received and studied the manufacturers' written literature about various thermal linings. EL&M has never tested any thermal lining materials. All of our understanding about the relative merits and problems with different thermal linings was acquired by talking to the lining manufacturers and the fire training academies that use those products. Our thermal lining recommendations are solely based on this information.

2. Various Types of Thermal Linings

EL&M knows of numerous types of thermal linings that are used in fire training burn buildings. These thermal linings offer a wide variety of thermal protection, durability, maintenance requirements, initial costs, and long-term costs. Some are proprietary, brand-name products while others are conventional materials applied in such a manner as to provide thermal protection.

2.1 Sacrificial Masonry (Fire Brick, CMU, or Patio Block)

Standard masonry, such as *fire brick* or *CMU*, can be placed adjacent to structural elements to act as thermal protection. The sacrificial masonry becomes damaged, or "sacrificed", so that the structural element behind it will not become damaged. When this non-structural sacrificial masonry has deteriorated significantly, it is demolished and replaced with new sacrificial masonry.

Sacrificial masonry is frequently used to protect structural walls. Often, the sacrificial masonry is placed against structural bearing walls within 6' to 10' of a burn corner. In other cases, where fires are set in several locations within the burn room, all four walls of the burn room are protected with sacrificial masonry.

Sacrificial masonry is also used to protect the top surface of concrete floor slabs. Fire brick and standard patio block are placed on floors, either with or without mortar, to keep floors protected from direct contact with fires. The fire brick or patio block can be placed within 6' to 10' of a burn corner or on the entire burn room floor (a better solution because it protects the entire floor from pallets that roll off the fire and from heat that banks down).

Occasionally, sacrificial masonry is used to construct a free-standing burn box, with three walls constructed of non-structural fire brick and/or CMU, and a fire brick floor. Some burn boxes also have a steel plate top, although there seem to be few merits to adding the plate because it does not insulate the ceiling structure above.

Specific manufacturers of fire brick, CMU, and patio block have not been contacted.

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	N/A	Both fire brick and patio block are reported to work well on floors. Fire brick should be a better insulator than patio block and can also be applied to walls. Mortar is not required in floor applications – just push bricks tight together.
Thermal shock resistance	N/A	Good resistance reported, but masonry placed with mortar can crack due to thermal movements and needs to be replaced periodically due to damage. Masonry is porous and absorbs water. Trapped water can cause the face of the masonry to spall when heated. When placed loose on floors (without mortar), thermal shock resistance appears to be high.
Max. recommended temperature	N/A	Unknown.
Resistance to mechanical abuse	N/A	Good. Masonry is not damaged when hit with a direct hose stream, pallet, breathing pack, or hand tools unless struck with an unusually heavy impact.
Required mainten-ance & replacement frequency	N/A	Fire brick or CMU protection on walls at burn corners requires replacement every 2 to 10 years on average, depending on training frequency. Fire brick or patio block on floors requires replacement every 10 to 20 years on average. At areas away from live fires, fire brick or CMU could last over 20 years in certain circumstances.

Characteristic	Reported by Manufacturer	Reported by burn building users
Initial cost (installed)	N/A	Patio block placed loose on floor costs approximately $4 per square foot for materials, assume $8 per square foot installed. Fire brick placed loose on floor costs approximately $6 to $8 per square foot for materials, assume $12 per square foot installed. Fire brick wall protection costs approximately $10 per square foot for materials, assume $20 per square foot installed.
Annual maintenance & repair costs	N/A	Cost to replace masonry every 2 to 20+ years, when it is destroyed.

2.2 Precast Concrete Burn Box

Precast concrete burn boxes are sometimes used to contain Class A fires. These rectangular boxes usually have 3 walls, a top, and a bottom. Class A materials are burned in the box in order to protect the burn room structure from flame impingement. Each burn box typically costs approximately $1,500 to $2,000 installed.

Specific precast concrete manufacturers have not been contacted to further research the burn box capabilities. Fire training academy personnel report that precast burn boxes provided only limited protection for the structure from heat and the boxes become damaged rather quickly (often in less than 2 years).

2.3 Metal Burn Pans and Burn Barrels

Standard metal barrels and flat metal pans have been placed in burn rooms to keep fires up off of the floor and to restrict the size of the fire (the stack of Class A materials in the container cannot be larger than the container itself). Barrels are usually standing upright or cut in half and placed horizontally on the floor to act as a pan. Typical flat pans are approximately 3'-0" or 4'-0" square and supported on four metal legs.

Barrel and metal pan fabricators were not contacted for this project.

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	N/A	Helps keep fires from damaging the floor slab, but does not insulate the remainder of the structure from the high temperatures.
Thermal shock resistance	N/A	Warps when heated to high temperatures and when exposed to thermal shock.
Max. recommended temperature	N/A	Unknown, but steel should begin to warp at approximately 1,200° F. Since fires are immediately against the barrels and pans, nearly every burn evolution will heat the metal to 1,200° F or higher.
Resistance to mechanical abuse	N/A	Excellent. Barrels and metal pans are not damaged when hit with a direct hose stream, pallet, breathing pack, or hand tools.
Required mainten-ance & replacement frequency	N/A	Barrels and pans warp severely and often. Must replace every 2 months to 2 years at frequent burn areas, perhaps every 10 years at less frequent burn areas.
Initial cost (installed)	N/A	None reported, but should be relatively inexpensive.
Annual maintenance & repair costs	N/A	Cost to replace barrels or metal pans every 2 months to 2 year at frequent burn areas, perhaps every 10 years at less frequent burn areas..

2.4 Steel Plate

Standard steel plates have been placed adjacent to structural elements to provide thermal protection. Steel plates are often placed over burn areas by either (1) hanging the plate from the structural slab above, (2) supporting the plate on the walls of a sacrificial masonry burn box, or (3) supporting the plate on steel posts attached to a metal burn pan. Fire training academy personnel often refer to steel plates as "heat shields". This is an inaccurate term because, in reality, **steel plates do not provide thermal protection and are not recommended for use in burn buildings**. Although steel plates help protect the structure to a limited degree by preventing direct flame impingement on the structure, heat passes through steel quickly, which can still damage the structural elements that are hidden behind the plates.

Specific steel fabricators have not been contacted to further research steel plate capabilities as thermal linings.

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	N/A	Helps reduce flame impingement on the structure but does not insulate the structure from the heat.
Thermal shock resistance	N/A	Warps when heated to high temperatures and when exposed to thermal shock.
Max. recommended temperature	N/A	Unknown, but steel should begin to warp at approximately 1,200° F.
Resistance to mechanical abuse	N/A	Excellent. Steel plate is not damaged when hit with a direct hose stream, pallet, breathing pack, or hand tools.
Required mainten-ance & replacement frequency	N/A	Due to warping, must replace plate every 2 to 5 years.
Initial cost (installed)	N/A	None reported, but the cost of a steel plate liner should be approximately $25 to $30 per square foot installed.
Annual maintenance & repair costs	N/A	Cost to replace steel lining every 2 to 5 years, when it is destroyed.

2.5 Refractory Concrete, Including the Brand Name of Fondag

Refractory concrete is also known as *calcium aluminate concrete*. Typically, the concrete is produced using calcium aluminate cement with either normal weight or lightweight aggregates. Fondag is a brand name refractory concrete made with calcium aluminate cement and calcium aluminate aggregate. Fondag is denser than standard concrete, with a density of 170 pounds per cubic foot (pcf) (normal weight concrete weighs 150 pcf, and lightweight concrete weighs between 80 pcf and 120 pcf). Fondag has been used for the same cast-in-place structural applications as generic refractory concrete.

Refractory concrete tends to be more resistant to heat, especially because it does not spall like Portland concrete does. Refractory concrete is frequently used, with success, as a thermal lining to protect building structures within industrial furnace applications. Many burn building designers have looked to this success and used refractory concrete to cast the structural slabs and walls, thinking that such structural elements would not require additional thermal linings to protect them from heat and thermal shock.

Unfortunately, this is not a good application for refractory concrete. While it is true that refractory concrete does not spall when exposed to live fires in burn buildings, it deteriorates in other significant ways. First, refractory concrete loses much of its strength when exposed to hot, moist environments. Humid summer days as well as the heat and steam associated with live fire training weaken the refractory concrete over time. When used as structural roofs, floors, beams, columns, and walls, this loss of strength becomes a structural concern. Second, refractory concrete still expands and contracts dramatically when exposed to the heating/cooling cycles in burn buildings. This causes cracks and delaminations within refractory concrete slabs just as it would within Portland concrete slabs. Third, the unique chemical composition of refractory concrete contributes to accelerated carbonation within the concrete, which is one contributor to reinforcing bar corrosion.

The combination of strength loss, cracking, and reinforcing corrosion in refractory burn buildings can lead to eventual delaminations throughout the entire structure, especially at the reinforcing bar layer(s). Delaminations in floor and roof slabs can extend literally from wall to wall. This is dangerous for trainees and instructors. Take the example of an 8" thick slab reinforced with one layer of rebar at the middle of the slab. The delamination occurs at the reinforcing layer, splitting the bottom 4" of the slab away from the rebar and from the top half. Thus, the bottom of the slab is unreinforced concrete just "hanging" over the rooms, waiting to fall. In a 12' x 12' burn room, this is 7,200 pounds of concrete sagging over the room. There is no telling if or when it would fall and there would be practically no warning to personnel in the room before it came down. This dangerous condition is hidden from view, not detectable by sounding, and only found through concrete testing (sounding is usually a very reliable method for locating delaminations in standard, non-refractory concrete but not in refractory concrete).

Of the seven refractory concrete burn buildings greater than 10 years old that EL&M has evaluated, all seven had experienced this delamination phenomenon. All seven had to be replaced entirely. This structural system should be avoided in burn buildings. As a result, **EL&M recommends against using refractory concrete as a structural material for burn building construction or as a thermal lining.** NFPA has also recognized this concern, requiring existing refractory concrete burn buildings to be inspected by an engineer annually, with concrete cores removed every three years to check for delaminations (see NFPA 1403).

Refractory (calcium aluminate) concrete can be batched by many different concrete suppliers. The specific product Fondag is manufactured by:

Lafarge Calcium Aluminates, Inc.
9033 Laurel Branch Circle
Mechanicsville, VA 23111
(804) 550-0693
(804) 550-0798 (fax)

Characteristic	Reported by Lafarge	Reported by burn building users
Thermal protection for structure	N/A, since Fondag is used as the structural concrete.	N/A
Thermal shock resistance	Will crack, but won't spall, due to thermal shock.	Cracks through entire slab thickness, with water leaking through the cracks. Survey findings also indicate significant delaminations at reinforcing layers, creating significant structural and safety problems.
Max. recommended temperature	2,100° F sustained.	Unknown
Resistance to mechanical abuse	Excellent. Fondag is a dense concrete that is not damaged when hit with a direct hose stream, pallet, breathing pack, or hand tools.	Excellent. Calcium aluminate concrete is not damaged when hit with a direct hose stream, pallet, breathing pack, or hand tools.
Required mainten-ance & replacement frequency	Seal cracks to keep moisture from reaching structural reinforcing.	Unknown.
Initial cost (installed)	None provided, but the calcium aluminate cement can more than double the cost of the ready-mix concrete material used to construct the building.	Unknown.
Annual maintenance & repair costs	Seal cracks - costs can vary.	Unknown.

2.6 Shotcrete (Spray-On or Gunite) Refractories

Shotcrete refractory, sometimes called "spray-on refractory" or "Gunite", is a concrete product usually produced with lightweight aggregate and calcium aluminate cement binder that is pneumatically applied to a structural element. The pneumatic application method is known as shotcrete. This method has been used to cover vertical, horizontal, and overhead surfaces with refractory concrete, though it is most often used to cover overhead (ceiling) surfaces and vertical (wall) surfaces.

Before application, a layer of welded wire mesh is wire-tied to pins that are shot into the structural wall or ceiling. The mesh typically hangs 1-1/2" to 4" from the protected element. Once the mesh is in place, the shotcreting consists of pneumatically pumping a dry mixture of cement and aggregate through a hose. Water and other admixtures are added at the exit nozzle of the hose. The wet cement mixture is propelled at high velocity onto the structural element that is to be protected. The shotcrete is usually applied in 1" layers up to the typical refractory thickness of 2" to 8", and then left to cure.

Shotcrete refractory manufacturers indicate that their products provide only average thermal protection. The refractory could require replacement at a frequency of every four to ten years. It has been observed to split down the middle at the welded wire mesh layer, much like poured-in-place refractory concrete splits at the reinforcing layer. When the shotcrete refractory splits at the mesh layer, it falls off of the ceiling or wall in small, though still dangerous, sections.

Given these concerns plus a relatively high installation cost, **shotcrete (spray-on or gunite) refractories are not recommended for use as thermal linings in burn buildings.**

Shotcrete refractories are made by several manufacturers. Lafarge Calcium Aluminates, Inc. produces a shotcrete refractory with its Fondag concrete product. Another manufacturer of shotcrete refractories is:

A.P. Green Refractories, Ltd.
Mexico, Missouri
(573) 473-3626
(573) 473-3330 (fax)

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	Varies depending on the application. Manufacturer could not provide any data.	Same thermal protection that concrete of that thickness would provide, which in most cases is adequate.
Thermal shock resistance	Product will crack when exposed to thermal shock.	Shotcrete cracks when exposed to thermal shock.
Max. recommended temperature	Manufacturer could not provide any data.	Unknown.
Resistance to mechanical abuse	Excellent.	Excellent – not damaged when hit with a direct hose stream, pallet, breathing pack, or hand tools unless impact is unusually hard.
Required mainten-ance & replacement frequency	Depends on use and training frequency. Manufacturer would not comment on how often refractory would have to be reapplied.	Shotcrete can split down the middle, especially if reinforced with mesh. Once it splits, pieces begin to fall off walls and ceilings, requiring patching and eventually full replacement.
Initial cost (installed)	Approximately $40 to $45 per square foot installed.	Approximately $40 to $45 per square foot installed.
Annual maintenance & repair costs	Depends on use and training frequency.	No annual maintenance, but might have to replace entire lining in 3 to 10 years.

2.7 Exposed Insulation Boards

Exposed, rigid insulation boards, usually made of calcium silicate, are commonly used in burn buildings as a thermal lining for ceilings and/or walls. There are several brand names and a variety of densities for these boards.

Each board is typically 1" thick by 4'-0" x 4'-0", 4'-0" x 2'-0", 2'-0" x 2'-0", or 15" x 15". The boards can have a similar appearance to standard drywall. The boards are hung with screws (typically nine screws per board) from a series of steel hat channels that are usually spaced on a 4' x 2' grid. The insulation boards are hung with gaps between adjacent boards plus oversized holes and washers at the screws, to allow for expansion and contraction. Batten strips of additional insulation boards are placed behind the gaps between the boards to stop heat from penetrating the system. There is an air space between the primary insulation boards and the structural wall/ceiling being protected. This air space helps the insulating capabilities of the system but requires the insulation boards to span the distance between the batten strips. Impact loads applied between the batten strips have to be resisted by the insulation boards. Sometimes these loads overstress the insulation boards in bending or shear, causing cracks or breaks. This, and temperatures that exceed the insulation rating, appear to be the leading causes for cracks or failures in the boards.

Unless treated with water repellent coatings, the insulation boards tend to absorb and hold water when sprayed with hoses, requiring several days to dry. During the drying time, live fire training evolutions cannot be conducted, restricting training schedules. As a result, suppliers of exposed insulation boards treat the boards with water repellent coatings before selling them for use in burn buildings.

BNZ Materials, Inc. (www.bnzmaterials.com), of Littleton, CO manufactures calcium silicate insulation boards with various densities but does not seem to sell them directly for use in burn buildings. BNZ does sell its various insulation boards to other companies, which treat the boards with water repellent coatings and repackage them with a different brand name.

There are currently seven known brand names for exposed insulation boards, three of which are still available, one by Fire Facilities, Inc. (FFI), two by WHP (formerly Werner-Herbison-Padgett), and one by Fireblast Global.

WHP
9130 Flint
Overland Park, KS 66214
(800) 351-2525

Fire Facilities, Inc
314 Wilburn Road
Sun Prairie, WI 53590
(800) 929-3726

Fireblast Global
545 Monica Circle
Corona, CA 92880
(951) 277-8319

Brand Name	Supplier	General Information
Westemp	FFI	4'-0" x 4'-0" calcium silicate insulation board introduced in the 1980s. Marinite I ("eye", not "one), by BNZ, or similar insulation board, treated with a water repellent and resold as Westemp.
Padgenite I ("one" not "eye")	WHP	Calcium silicate insulation board introduced in the 1980s. Marinite I ("eye", not "one), by BNZ, or similar insulation board, treated with a water repellent and resold as Padgenite I.
Padgenite II (no longer available)	WHP	Calcium silicate insulation board introduced circa 2000. Marinite P, by BNZ, or similar insulation board, treated with a water repellent and resold as Padgenite II. This board is denser and more expensive than Padgenite I or Westemp. WHP no longer sells Padgenite II.
Super Padgenite (no longer available)	WHP	Calcium silicate insulation board introduced in 2002. Marinite A, by BNZ, or similar insulation board, treated with a water repellent and resold as Super Padgenite. This board is heat treated, to make it more resistant to higher temperatures. It is denser and more expensive than Padgenite II. WHP no longer sells Super Padgenite.
Duraliner HT (no longer available)	WHP	Non-asbestos fiber cement board, similar to Transite 1000, by BNZ, introduced by WHP in 2004. It is denser and more expensive than Super Padgenite. WHP no longer sells Duraliner.
Padgenite Super HD	WHP	4'-0" x 2'-0" calcium silicate insulation board introduced in 2012. The insulation board is by BNZ, similar to Marinite A, but slightly different to make it proprietary to WHP. It is treated with a water repellent and sold exclusively as Padgenite Super HD.
Padgenite Interlock	WHP	15" x 15" calcium silicate interlocking insulation board introduced in 2022. The insulation board is by BNZ, similar to Marinite A, but slightly different to make it proprietary to WHP. It is treated with a water repellent and sold exclusively as Padgenite Interlock.
Thermablast	Fireblast	2'-0" x 2'-0" panel system similar to Padgenite Super HD.

The exposed insulation boards have a track record of providing good thermal protection for burn buildings as long as they remain intact. Exposed insulation boards have a history of requiring periodic, sometimes frequent, replacement due to cracking and breaking when exposed to live fire training. The denser the board, the less thermal protection provided (though it is likely adequate for live fire training) but the more durable it is against mechanical abuse (impact by hose streams, tools, equipment, SCBA tanks, and tossed pallets). It appears that the discontinued boards are no longer available because they did not perform at a high enough level and were replaced with newer board options that were anticipated to perform better.

For exposed insulation boards:

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	If 1,000° at face of panels, 290° F or less (depending on the board) behind panels. Cracked panels allow heat to reach structure.	Good protection as long as the panels are not cracked. If panels are cracked, structure behind panels gets damaged.
Thermal shock resistance	Can withstand repeated exposure to heat and water without breakdown of insulating properties.	For less dense, non-heat-treated boards: Good if heat levels are kept low. Under high temps, panels crack when hit with a hose stream and sometimes just from the high temperature. For heat-treated, denser boards: More heat and thermal shock resistant than less-dense boards.
Max. recommended temperature	1,200° F for Marinite I, Westemp, Padgenite I, and Padgenite II. 2,000° F for Super Padgenite, Duraliner HT, Padgenite Super HD, Padgenite Interlock, and Thermablast. BNZ, which makes the base materials for all listed panels states that maximum service temperature depends on the application, except for Transite 1000 (the base product for Duraliner HT), for which BNZ states that maximum operating temperature is between 600° F and 1,000° F.	Unknown.
Resistance to mechanical abuse	Excellent	Panels sometimes crack when hit with direct hose stream, SCBA tank, pallet, or hand tools. Denser boards require less frequent replacement than less dense boards but still require periodic replacement.

Characteristic	Reported by Manufacturer	Reported by burn building users
Required mainten-ance & replacement frequency	When a panel cracks partway through its thickness, it can be flipped and rehung or patched with sealing materials provided by supplier. When the panel is cracked through its entire thickness or broken, it must be replaced. Replacement frequency is usually once every 10-15 years, depending on intensity of training.	When a panel cracks partway through its thickness, it can be flipped and rehung or patched with sealing materials provided by supplier. When the panel is cracked through its entire thickness or broken, it must be replaced. Replacement frequency can vary from one training day to ten+ years. Some facilities go several years between panel replacements while others replace 25% of the panels annually.
Initial cost (installed)	$50 to $60 per sq. foot for Westemp and Padgenite I $70 to $80 per sq. foot for Padgenite Super HD and Thermablast.	$50 to $60 per sq. foot for Westemp and Padgenite I $70 to $80 per sq. foot for Padgenite Super HD (no references reached yet for Thermablast but it is assumed it will perform similarly to Padgenite Super HD).
Annual maintenance & repair costs	Depends on intensity of training. $40 per square foot to replace cracked panels of Westemp and Padgenite I, $60 for Padgenite Super, excluding labor.	Between $200 and $20,000 per year, depending on the quantity of lined rooms and training intensity.

2.8 Hybrid Systems by High Temperature Linings

High Temperature Linings (HTL) System 203 is a hybrid system consisting of a 1" thick rigid calcium silicate insulation boards (similar to Marinite I but less dense) plus a series of 1-3/4" thick, 12" x 12" thermo-ceramic refractory tiles covering the insulation boards. The tiles are made with calcium aluminate refractory concrete mixed with stainless steel fibers and other materials, distinguishing them from ceramic tiles. The insulation boards are screwed directly to the structural wall/ceiling being protected with no gaps between the boards and no air space between the boards and the structure. The tiles completely cover the insulation boards, with a ship-lapped joint between each tile on all four edges, and a stainless steel expansion anchor at the center of each tile to anchor it to the structural wall/ceiling. The bolt holes are oversized and the joints between tiles are not sealed, to allow for expansion and contraction. The insulation boards provide the insulating barrier. The tiles provide the protection for the insulation boards, to protect the boards from excessive heat, thermal shock, and physical abuse inherent in live fire training (impact from tools, SCBA tanks, tossed pallets, high pressure hose streams, etc.). This system was introduced circa 1987 in England and 1994 in the U.S.

HTL System 203 is manufactured by:

High Temperature Linings
PO Box 1240
White Stone, VA 22578
(800) 411-6313
(804) 436-8121
(757) 257-6065 (Fax)

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	If 1,800° at face of tiles, 205° F behind insulation layer at the back of the tiles.	If 1,800° F at face of tiles, less than 300° F behind lining.
Thermal shock resistance	"Excellent. No effects from thermal shock with temperatures up to 2,200° F."	Excellent. No damage due to hitting heated tiles with cold water.
Max. recommended temperature	1,800° F sustained, with a spike of 2,000° F.	Have covered the entire floor of a room repeatedly with a 5' tall stack of pallets *(not recommended)* without damaging the tiles or reaching temperatures above 300° F behind the lining.
Resistance to mechanical abuse	Excellent. Won't get damaged by direct hose stream, SCBA tank, thrown pallets, or hand tools. Vulnerable to ice damage if substrate material (ceiling slabs or walls) leaks.	Excellent. No damage due to mechanical abuse. Vulnerable to ice damage if substrate material (ceiling slabs or walls) leaks.
Required mainten-ance & replacement frequency	Must replace fire clay over countersunk bolt heads when it deteriorates. Approximately 10% of the bolt heads every year. Fewer than 50 tiles have been replaced out of 200,000 installed since, and those were replaced by manufacturer at no cost to Owner even though the tiles were still functioning properly.	No tiles have had to be replaced at cost to owner except a few cases where the substrate leaked, causing ice damage to the thermal lining system. Otherwise, only maintenance required is replacing fire clay over countersunk bolt heads. Ex.: After 1 to 2 years, in 6 burn rooms, a total of 100 bolt heads need new fire clay.
Initial cost (installed)	$75 to $90 per square foot, depending on freight and prevailing wages.	$75 to $90 per square foot.
Annual maintenance & repair costs	Depends on intensity of training, but maintenance will be "minimal".	Approximately $100 or less per year.

2.9 Hybrid System by FFI

Westec is a hybrid thermal lining system by FFI that protects walls/ceilings. It consists of galvanized zee channels attached to the structure, spun ceramic insulation blankets between the channels, and 24 ga. stainless steel panels covering the channels and blankets. The steel panels have slip connections to allow for expansion and contraction. Westec was introduced in 2003.

Fire Facilities, Inc
216 Wilburn Road
Sun Prairie, WI 53590-9401
(800) 929-3726
(866) 639-7012 (Fax)

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	If 1,850° at face of tiles, less than 300° F behind insulation layer.	Good thermal protection as long as insulating blanket is in place and dry behind panels.
Thermal shock resistance	Excellent. No effects from thermal shock	Warping and loose screws due to heat and thermal shock, from minor to severe.
Max. recommended temperature	1,800° F sustained (supplier recommends maximum of 1,200° F for safety).	Unknown.
Resistance to mechanical abuse	Excellent. Won't get damaged by direct hose stream, SCBA tank, thrown pallets, or hand tools.	Good – warping appears to be caused by thermal changes more than mechanical abuse.
Required mainten-ance & replacement frequency	Expected to be minimal if temperatures are kept below 1,200° F.	Replacement of warped panels and screws that fail due to panel warping.
Initial cost (installed)	$60 to $70 per square foot, depending on prevailing wages and freight.	$60 to $70 per square foot installed.
Annual maintenance & repair costs	Expected to be minimal if temperatures are kept below 1,200° F.	Insufficient information gathered to date. Routine replacement of warping steel panels reported, not covered by warranty.

2.10 FireMaster Ceramic Tiles, by Thermal Ceramics

FireMaster tiles are 1'-0" x 1'-0" x approximately 3/4" thick ceramic tiles. In a typical burn room application, FireMaster tiles are attached to the entire surface of ceilings and walls with one screw just off-center in each tile. The narrow gaps between tiles are not sealed. FireMaster tiles have been installed with or without a 1/2" thermal insulation blanket behind the tiles.

Based on reports by fire training academy personnel, this product is fragile and requires frequent replacement. As a result, **FireMaster Ceramic Tiles are not recommended for use as thermal linings at burn buildings.**

FireMaster tiles are manufactured by:

Thermal Ceramics
P.O. Box 923, Department 140
Augusta, GA 30903-0923
(706) 796-4280
(800) 245-8008
(706) 796-4324 (fax)
(800) 458-4452 (nationwide technical support)

Characteristic	Reported by Manufacturer	Reported by burn building users
Thermal protection for structure	During a single, 30-minute burn evolution, if 1,400° at face of tiles, 443° F behind tiles if no insulation, 183° F behind tiles if 1/2" insulation blanket is used. Cracked panels allow heat to reach structure.	If 1,200° F at face of tiles, 1,000° F behind tiles (this was an application with no insulation blanket behind tiles).
Thermal shock resistance	Excellent. "Can heat the tiles until they are red hot, drop them in a bucket of cold water, and there will be no damage."	Tiles crack when hit with a direct hose stream, either because of thermal shock or because of the water pressure.
Max. recommended temperature	None stated.	Unknown, but lack of insulation in the installation indicates temperatures should be kept under 1,000° F.

Characteristic	Reported by Manufacturer	Reported by burn building users
Resistance to mechanical abuse	Excellent. "Won't get damaged by direct hose stream, breathing pack, or hand tools." However, Thermal Ceramics is aware of problems at certain locations and hypothesizes that the screws supporting the tiles were overtightened when installed, making the tiles susceptible to damage under light mechanical abuse.	Tiles crack, shatter, and fall off the walls and ceiling when hit with direct hose stream, breathing pack, pallet, or hand tools.
Required mainten-ance & replacement frequency	When a tile is cracked or otherwise damaged, it must be replaced. Replacement frequency has not been determined.	When a tile is cracked, it must be replaced. Nearly all of the tiles at the burn areas require replacement after one year (approximately 10% of all of the tiles in the building).
Initial cost (installed)	$33 per square foot for materials only (does not include installation) reported in 1996.	$38 per square foot for materials only (does not include installation) in 1992.
Annual maintenance & repair costs	Depends on intensity of training.	$7,200 worth of tiles (material only, no labor) required replacement in the first year at one facility in 1992.

3. Questions to Ask Facilities that have Linings In Order to Compare Products

When contacting facilities that have thermal linings, the following questions should be asked in order to properly compare different thermal lining products.

1. Do you have a metal burn building or a concrete/masonry burn building?
2. Is the building structure (excluding thermal linings, doors, windows, temperature monitoring devices, or other non-structural items) in good condition?
   - Has a structural engineer evaluated it recently as required by NFPA 1402?
   - Have you ever had to make repairs or routine maintenance to the metal or concrete/masonry structure?
3. Do you use Class A fuels or gas-fired trainers?
4. How many live fire training days do you have per year?
5. How many live fire training evolutions do you have per training day?
6. At the burn building, do you train just those firefighters in your municipality or do firefighters from all around the region use the facility?
7. Do you use direct hose streams or fog spray?
8. What temperatures do you typically reach during live fire training (if you have a temperature monitoring system)?
9. What type of thermal lining do you have?
10. Have you ever had to replace any part of the thermal lining?
11. How often do you have to replace or repair lining panels?
12. Do certain room locations require more frequent lining repairs than others?
13. What causes the damage to the thermal lining panels?
14. What are the annual costs and down-time associated with thermal lining maintenance and repairs?
15. Are you happy with your thermal lining? Why?
16. Did you have a different kind of thermal lining in the past? If so, why did you change?
17. Are you happy with your overall burn building? Why?

4. Recommended Thermal Lining Systems

The purpose of a thermal lining is to reduce structural deterioration caused by repetitive live fire training. Two significant benefits are achieved by protecting the structure: (1) prolonging the life of the burn building, and (2) making the training facility safer for firefighters and instructors. Safety is improved when the structure is protected from heat and thermal shock. By adding thermal linings, concrete ceilings are less likely to spall and drop concrete on personnel below; masonry walls and partitions are less likely to crack, move, and become unstable; and steel beams and roof deck are less likely to warp, sag, or fail. The linings recommended in the report will not prevent all future structural damage, but should reduce structural deterioration and prolong the life of the building. Repairs and maintenance for the structure and lining can be anticipated in the future and should be included in budget planning.

EL&M recommends the installation and maintenance of thermal linings in every burn room of every burn building to protect the structure from high temperatures and thermal shock. Different thermal linings offer different capabilities. Typically, the more expensive lining systems offer better thermal protection. However, no thermal lining is guaranteed to provide absolute protection for the building structure. Maintenance of the lining system is critical to its effectiveness and to prolonging the life of the structure.

The recommended thermal lining for this building is stated in the main body of the report. Selecting which thermal lining to recommend depended on several factors: (1) number of annual burn evolutions reported by the facility, (2) degree of training supervision provided by the local training academy, (3) temperatures during training, (4) thermal protection provided by the lining, (5) durability of the lining, (6) initial cost of the lining, and (7) maintenance requirements of the lining. High quality, expensive linings are typically recommended for those burn buildings with more severe training conditions. However, for facilities with infrequent and less severe training, less expensive linings can still offer enough thermal protection to significantly prolong the life of the building.

If any of factors 1 through 3, noted above, change in the future, the thermal lining should be reevaluated and, if necessary, upgraded.

5. Thermal Lining Systems That Are Not Recommended

Several thermal linings are not recommended for use in any burn building. This conclusion is based on observations made during the dozens of burn building surveys and problems reported by the burn building owners and users. EL&M has not performed testing on these linings.

The following lining systems should not be used:

1. Refractory Concrete as structural elements (slabs, bearing walls, columns). As observed at many existing refractory concrete burn buildings, this material has a tendency to delaminate at the reinforcing layers within structural elements. This creates a significant structural and safety problem that is hidden from view. It is recommended that standard Portland cement concrete buildings with a good thermal lining be constructed instead of refractory concrete structures.

2. FireMaster ceramic tiles, manufactured by Thermal Ceramics. As installed at various burn buildings, with no insulation behind the tiles, this lining offers virtually no thermal protection for the structure after repetitive evolutions. Tiles have cracked and fallen off of walls and ceilings in less than one year in some applications.

3. Shotcrete (Spray-On) Refractory. Shotcrete refractory manufacturers indicate that their products provide only average thermal protection. The refractory could require frequent replacement and can create safety problems when it starts to split and fail. It is also relatively expensive, making the maintenance and future replacement costs high.

4. Steel plates. Many fire training academies like the fact that the plates are relatively inexpensive, reduce flame impingement on ceiling structures, and only have to be replaced every 2 to 5 years. However, the plates offer no thermal protection for the building structure other than deflecting the flames. High temperatures and thermal shock cause the most significant structural damage, and steel plates offer little protection against these items. It is possible to place insulation boards behind the steel plates to improve the insulating capabilities of the system. However, this increases the cost of the lining system to nearly that of the most expensive lining option but, because of the tendency of the plates to warp and require periodic replacement, does not offer the durability. Therefore, there do not appear to be any good reasons to use steel plates as thermal linings. This conclusion also follows normal building construction practices: in an office building, concrete is used as fire protection for steel but steel is never used as fire protection for concrete.

struc'tur'al

Ethan Porter
21 Alpha Road, Suite 203
Chelmsford, MA 01824
Mobile: (857) 360-5297
eporter@structural.net
www.structural.net

Proposal No. FY23-645089
Milford Fire Burn Building Make-Safe
March 29, 2023

Mike DeTore
Milford Fire Department
21 Birch Street
Milford, MA 01757

Re: Milford Fire Burn Building Make-Safe

Dear Mike:

Thank you for giving STRUCTURAL the opportunity to prepare a proposal for the make-safe repairs to the training building at 21 Birch Street, Milford, MA 01757.

STRUCTURAL trusts that we have provided adequate detail for your evaluation and that we have expressed our desire to work with your company on this project. The following outlines the project scope of services, working conditions, exclusions and support by others, safety considerations, estimated schedule, financials, suggested next step and attachments as they relate to this project.

SCOPE OF WORK

1) General Conditions:
   a) Mobilize all crew and equipment to the proposed work site. Demobilize upon completion of the work. This proposal is based on performing all work in one mobilization.
      i) This proposal is based on the client providing full access to the entire building.

2) Overhead De-Spalling (up to 60 SF):
   a) Remove any visually obvious loose concrete by means of hand tools (i.e., hammers) and dispose of debris off site.

3) Repair of Third-Floor Beam (up to 12 LF):
   a) Sound out the surface of the beam to identify any delaminated areas.
   b) Install shoring as needed and remove after repairs have reached sufficient strength.
   c) Sawcut the perimeter of the delaminated areas ½" deep.
   d) Remove section of the beam using chipping hammers, up to 3" deep. Dispose of debris off site.
   e) Clean the spall cavity and any existing reinforcing steel by means of sandblasting, water blasting, or equal.
   f) Replace any deteriorated reinforcing steel that has lost more than 20% of its cross-sectional area.
   g) Place, finish, and cure new repair mortar such as SikaQuick VOH by Sika, or equal.

4) Slab-on-Grade Concrete Spall Repairs (up to 50 SF):
   a) Sound out the topside of the slab to identify the delaminated areas.
   b) Sawcut the perimeter of the delaminated areas ½” deep.
   c) Remove the delaminated and deteriorated concrete using pneumatic and/or electric chipping hammers, up to 3” deep. Dispose of debris off site.
   d) Clean the spall cavity and any existing reinforcing steel by means of sandblasting, water blasting, or equal.
   e) Replace any deteriorated reinforcing steel that has lost more than 20% of its cross-sectional area.
   f) Place, finish, and cure new repair mortar such as MasterEmaco T1060 by Master Builders Solutions, or equal.

5) Wall Corner Concrete Spall Repairs (up to 5 SF):
   a) Sound out the vertical surfaces to identify the delaminated areas.
   b) Sawcut the perimeter of the delaminated areas ½” deep.
   c) Remove the delaminated and deteriorated concrete using pneumatic and/or electric chipping hammers, up to 3” deep. Dispose of debris off site.
   d) Clean the spall cavity and any existing reinforcing steel by means of sandblasting, water blasting, or equal.
   e) Replace any deteriorated reinforcing steel that has lost more than 20% of its cross-sectional area.
   f) Place, finish, and cure new repair mortar such as SikaQuick VOH by Sika, or equal.

WORKING CONDITIONS

1) This proposal is based on performing work during a single mobilization and uninterrupted work schedule while on site.
2) This proposal is based on performing all work in a maximum of 1 phase
3) This proposal is based on the following working hour assumptions
   a) Single daily shift of 8 hours.
   b) Daytime work hours.
   c) Five (5) day week MTWTF.
   d) This proposal is based on the following labor rate assumptions
      i) Prevailing wages for Worcester County, Massachusetts as of the date of this proposal. Additional costs for escalation of wages after the date of this proposal shall be adjusted accordingly to the contract total.

SUPPORT BY OTHERS (at no cost to STRUCTURAL) SHALL INCLUDE THE FOLLOWING

1) Site utilities, including but not limited to:
   a) 110V, 220V, and/or 480V, 60 amp power electric available at existing outlets/panels.
   b) Toilet facilities.
   c) Potable water with minimum 35 psi pressure and ¾" spigot, located within 100' of the work area.
   d) Adequate Lighting per OSHA standards, i.e. 10 foot-candles of illumination.
   e) Payment for all required utility costs.
2) General site support, including but not limited to:
   a) Parking for employees, service vehicles, and 2nd tier sub-contractors.
   b) Storage area, including location for dumpster.

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SCOPE CLARIFICATIONS

1) Pricing is based on site conditions and logistics as of March 21, 2023. If site conditions change prior to or during the work schedule that may affect, access, ventilation, phasing, material handling, additional costs may apply.
2) STRUCTURAL is not responsible for damage to unknown embedded utilities.
3) All pricing given in this proposal represents current market prices and conditions for labor and materials. Increased costs due to changes in material prices, project delays due to material shortages and unexpected lead times, and labor rates at the time of delivery or during performance will be brought to the Client's attention with the understanding that equitable adjustments to the contract price will be made. Pricing also represents the current availability of materials, equipment and supplies needed for the proposed project. Changes in supply chain availability, once known, will be communicated to the client within three (3) business days and potential alternates will be proposed, if available.

EXCLUSIONS

1) Sales tax.
2) Permits and fees.
3) Testing and inspections.

4) Teamsters, Operating Engineers or any other union personnel.
5) Bonds and associated costs.
6) Design and any engineering.
7) Asbestos and other hazardous waste removal.
8) Air quality monitoring.
9) Concrete repairs of any nature including but not limited to cracks, spalls, scaling, etc.
10) Full height work area barricades / protection.
11) Steel work, including grouting, drilling and doweling for steel installations.
12) Electrical, mechanical and sprinkler work, including the removal and installation of fixtures.
13) The repair to hidden items in the slab, such as post-tension cables and conduits, that cannot be accurately located and are damaged by our work.
14) Any special safety requirements.
15) Any work specifically not included in this proposal.

PROJECT SAFETY CONSIDERATIONS

Safety is a core principle – there is nothing more important in what we do, 24/7. We owe it to our clients. We owe it to our employees. We owe it to the families of those that count on us. It’s a moral and ethical requirement of our business.

STRUCTURAL’s Frontline Safety Program in combination with a project-specific Safety Execution Plan will ensure that safety will be a primary measurement of success on this project.

PRICE

Lump Sum: $32,500.00 plus applicable taxes

PAYMENT TERMS

1) The mobilization charge will be invoiced upon arrival at the jobsite and will be payable in thirty (30) days.
2) Deposit: 10%
3) Invoices shall be submitted monthly and are payable within thirty (30) days from date of invoice. One and one-half percent (1.5%) interest per month is due on any unpaid balance after thirty (30) days.

CONTRACT TERMS

Please find below our proposed general conditions (Attachment A) for this agreement, where you may sign on the last page to approve this proposal.

If these are not acceptable, we are open to considering another form of agreement such as an AIA or EJCDC contract or the terms can be customized and mutually agreed upon.

EXPIRATION

This proposal may be withdrawn if not accepted within thirty (30) days of the date of this proposal.

Very Truly Yours,

STRUCTURAL PRESERVATION SYSTEMS, LLC.

Ethan Porter
Estimator

Attachment A
General Terms and Conditions

1. **Beginning Work**:
Structural Preservation Systems, LLC ("Contractor") shall be allowed reasonable time for delivery of materials and labor for required performance. Client shall use its best efforts to assure that the work area is accessible and appropriate for Contractor's work.

2. **Bonds & Insurance**:
   - 2.1. The cost of bonds is not included. If Performance and Payment Bonds are required, Client is responsible for all associated premiums and will satisfy Contractor's bonding company underwriting requirements including confirmation of funding and use of standard AIA A311/A312 bond forms.
   - 2.2. Contractor shall maintain the insurance coverages described below during the performance of the Services:
     - 2.2.1. Worker's Compensation as required by statute; Employer's Liability with a limit of liability of $1,000,000.
     - 2.2.2. Comprehensive General Liability including Completed Operations with the following limits:
       - 2.2.2.1. Bodily Injury - $2,000,000 each occurrence/$4,000,000 Aggregate
       - 2.2.2.2. Property Damage - $2,000,000 each occurrence/$4,000,000 Aggregate
       - 2.2.2.3. Automobile Liability on all owned, leased and hired automobiles with the following limits:
       - 2.2.2.4. Bodily Injury - $2,000,000 Each Occurrence
       - 2.2.2.5. Property Damage $2,000,000 Each Occurrence.

     Upon request, Contractor will provide a certificate of insurance which will include the Client as additional insured. Any other insurance required will be furnished at Client's sole cost, if available.
   - 2.3. Client (and/or Owner, if other than Client) shall insure, for their full insurable value, the Project site, and the Project itself against all losses and damages including, but not limited to, those which might result from risks insurable by a combination of a fire and extended coverage policy, a boiler and machinery policy, a business interruption policy, an ocean (and air) transit policy, and a broad form "All-Risks" policy, whichever coverage(s) are applicable to the Project. Client hereby waives all recovery and subrogation rights that it or its insurers may have against Contractor and its subcontractors for any losses or damages to the property to be insured under this subparagraph (c). If Client is not the Owner of the Project, it shall obtain a similar waiver from Owner for Contractor's benefit.

3. **Payment**:
   - 3.1. Payment is a material issue. Payment by Client for Contractor's performance is not subject to any contingencies or conditions. If payment is not made within thirty (30) days, Contractor may stop work after three (3) days' written notice to client without prejudice to any other remedy it may have including the right to file a lien, claim, or notice thereof. No back charges or claims shall be valid unless agreed to in writing by Contractor. Retainage shall not exceed 5% for the duration of the project.
   - 3.2. Client shall not withhold payments due to third party general liability claims if the liability for such claim(s) has been accepted by Contractor's insurer.

4. **Warranty:**
   - 4.1. Contractor warrants to the Client that the work described herein will be free from defects in material and workmanship. If within one (1) year from date of Substantial Completion of Contractor's Work, or as otherwise mutually agreed upon in writing between Contractor and Client, Contractor receives from the Client prompt written notice that the material or workmanship does not meet such warranties, Contractor will cure, within a reasonable amount of time, each such defect including nonconformance with the specifications, weather-permitting. THERE ARE NO OTHER REMEDIES, LIABILITIES (INCLUDING NEGLIGENCE) OR WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE APPLICABLE TO THE MATERIAL AND/OR SERVICES. Contractor's sole responsibility and Client's exclusive remedy is limited to repair or replacement as above provided.
   - 4.2. Any manufacturer's warranty provided for materials shall be provided as a direct warranty, which shall be enforceable only against the manufacturer. Client shall be solely responsible for enforcing any such warranty.
   - 4.3. Structural Preservation Systems, LLC does not provide a warranty for chemical grouting work.

5. **Delays**
   - 5.1. Contractor is not responsible for, and is entitled to extensions of time for, weather delays and other delays out of its control, (including, without limitation, those caused by; the Client, Owner (if not the Client), General Contractor, other contractors and subcontractors, Architects, Engineers; terrorism, armed conflict or economic dislocation; embargoes of labor, unavailability of materials, production facilities or transportation; labor difficulties; civil disorders of any kind; action of civil or military authorities; vendor priorities and allocations; or fires, floods, accidents and acts of God). In addition, Contractor can stop work if it considers the jobsite conditions unsafe or if another contractor working at the Project site is being unsafe.
   - 5.2. Contractor's liability for delay damages is limited to liquidated damages in an amount mutually agreed upon by Contractor and Client, if any, which shall be Client's sole and exclusive remedy for any damages resulting from Contractor's delay. In no event shall the aggregate amount of any liquidated damages exceed five percent (5%) of the contract price. Contractor shall not be liable for any other actual, punitive, indirect, incidental or consequential damages of any kind.
   - 5.3. If Contractor is delayed in any manner by the acts, errors, or omissions of the Client or Owner (if not the Client), their separate contractors (of any tier), Architect, Engineer, or by an employee or agent of any of them, then, in addition to any applicable extension of time, Contractor shall be entitled to compensation for any reasonable damages caused by the delay.

6. **Liability:**
   - 6.1. Contractor shall not be liable to any party for claims of any kind related to asbestos, lead paint or mold or any other hazardous materials. If Contractor encounters (1) hazardous materials, or (2) subsurface or latent physical conditions which differ from those disclosed to

Contractor in the Contract Documents or those ordinarily encountered at a site similar to the Project, then Contractor shall be entitled to an equitable price and schedule adjustment to compensate it for such conditions.

6.2. Liability or damages associated with water leakage shall be the responsibility of the Client unless caused by Contractor's sole negligence.

6.3. Client shall be responsible for any and all property damage and/or bodily injuries (including but not limited to injuries to Contractor's employees) that result from damage to interior and/or exterior underground/overhead/surface mounted/embedded utilities or structures unless caused by Contractor's sole negligence.

6.4. Contractor's responsibility for any claims, damages, losses or liabilities arising out of or related to its performance of this contract, including but not limited to any correction of defects under the Warranty, shall not exceed the contract price. Except to the limited extent provided in Section 5.b. above, in no event shall Contractor be liable for any special, indirect, incidental, consequential, delay or punitive damages of any character, including but not limited to: loss of use of productive facilities or equipment, lost profits, governmental fines or penalties, property damages, personal injuries or lost production, whether suffered by Client or any third party, irrespective of whether claims or actions for such damages are based upon contract, warranty, negligence, strict liability or otherwise.

7. **Indemnification**:

7.1. To the fullest extent permitted by law, Contractor shall indemnify and hold harmless the Client, its Engineer, and agents and employees of either of them from and against claims, damages, losses and expenses, including but not limited to attorney's fees, arising out of or resulting from performance of the Work, provided that such claim, damage, loss or expense is attributable to bodily injury, sickness, disease or death, or to injury to or destruction of tangible property (other than the Work itself), but only to the extent caused by negligent acts or omissions of Contractor, its subcontractor, anyone directly or indirectly employed by them or anyone for whose acts they may be liable.

8. **Dispute Resolution & Governing Law**:

8.1. All claims, disputes, and other matters and questions arising out of, or relating to this Contract or any breach which cannot be resolved through negotiation, may be submitted to mediation before the American Arbitration Association. If the dispute is not resolved through mediation, the parties may elect to proceed to binding arbitration before the American Arbitration Association in accordance with the Construction Industry Arbitration Rules then in effect. The prevailing party shall be entitled to recover all costs and reasonable attorney's fees incurred (whether pre-litigation, at mediation, arbitration or trial level and in any appeals).

8.2. Prior to exercising any remedies based on default, deficiency, delay or failure in the performance of the Work, the Client shall provide Contractor with prompt written notice and an opportunity to cure within a commercially reasonable time.

8.3. This contract shall be governed by the law of the jurisdiction in which the project is located.

9. **Price Escalation:**

9.1. All pricing given in this proposal represents current market prices and conditions for labor and materials. Increased costs due to changes in material prices, project delays due to material shortages and unexpected lead times, and labor rates at the time of delivery or during performance will be brought to the Client's attention and an equitable adjustment to the contract price will be made for the increased costs resulting from price and labor rate increases and extended project durations. Pricing and schedule also represents the current availability of materials, equipment and supplies needed for the proposed project. Changes in supply chain availability, once known, will be communicated to the client within three (3) business days, potential alternates will be proposed, if available, and the project schedule will be adjusted to correspond to material availability.

9.2. If the pricing for the Work includes unit prices, the unit prices specified assume that the designated quantities will be provided. If more or less than the specified quantities are actually provided, Contractor shall be entitled to an equitable adjust to the contract price to reflect loss of production efficiency, increased unit costs of production and/or installation and other similar factors.

10. **Mock-ups (if applicable):**

10.1. Contractor will prepare a mock-up based on the specified work scope for each repair item to set the quality and aesthetic standards for repair. Should the desired results not be achieved, further investigation and continued work may necessitate additional costs for the specified repairs. If the Client does not approve the mock-up, Contractor reserves the right to terminate the contract and recover all actual, incurred costs in completing the mock-up.

11. General Contractor Clients (if applicable):

11.1. If STRUCTURAL is contracting as a Subcontractor to a General Contractor, a copy of the prime contract and an electronic copy of the overall project schedule will need to be provided for review prior to contract execution and commencement of work.

The undersigned representatives of Structural and the Client have read and agreed to these Terms and Conditions that will control this project:

Structural Preservation Systems, LLC	Client Company:______________________________
Signature: ______________________	Signature: ___________________________________
Name: _________________________	Name: ______________________________________
Date: __________________________	Date: _______________________________________